PETROLEUM DEVELOPMENT AND TECHNOLOGY

1944

PETROLEUM DIVISION

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AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

(INCORPORATED)

and Petroleum

Volume 155

PETROLEUM DEVELOPMENT AND TECHNOLOGY

1944

PETROLEUM DIVISION

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FOREWORD

In furtherance of the object of the Petroleum Division to " . . . furnish a medium of cooperation among those interested in the petroleum industry, and to promote the advancement of this branch of mineral technology through meetings for professional and social intercourse, and to stimulate the preparation, reading, discussion and circulation of papers connected therewith," this volume of Petroleum Development and Technology is commended to the members of the Petroleum Division.

The Petroleum Division met during the Annual Meeting of the Institute at New York in February 1943, and instead of having two meetings in the fall, held a meeting in the Mid-Continent area in May at Dallas and another meeting at Los Angeles in October. The spacing of the meetings in this manner helped to make papers more currently available for PETROLEUM TECHNOLOGY and has distributed the work of the Papers and Programs Committee, as well as of the New York force, more evenly over the year.

The calling of many technical men into the services of our Country made it necessary for those left at their positions in civilian activity to assume additional duties and responsibilities. Much research work had to be curtailed or completely suspended because of the lack of trained personnel. Under these circumstances, those who took time from their crowded schedule to prepare and present technical papers deserve the thanks of the Petroleum Division. The Division is indebted also to the members of the Papers and Programs Committee and to all officers and committeemen who contributed to the outstanding success of the meetings.

To Mr. Chester Naramore, Executive Secretary of the Petroleum Division, much credit is due for the successful year of the Division. He has worked hard and enthusiastically in the interest of the members. Mr. E. J. Kennedy, Jr., Assistant Secretary, has been of invaluable help to the Papers and Publications Committee, and to him and to the New York office personnel the Petroleum Division extends its thanks for a good job well done.

In February 1944, a meeting of the Petroleum Division was held at the Waldorf-Astoria Hotel, New York, during the Annual Meeting of the Institute. Notwithstanding the absence of many personalities long identified with the Petroleum Division, the attendance was larger than ever before, which reflected the intense interest in the problems of the petroleum industry. The importance of oil in the war effort was clearly emphasized by the nature of the sessions and the large number of engineers who attended and participated in the discussions.

The Petroleum Division was host to the Regional Meeting of the Institute at Houston in May 1944, and the fall meeting is scheduled for Los Angeles in October.

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KILGORE, TEXAS,
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Surface Tension of Crude Oils Containing Dissolved Gases. By D. L. Katz, R. R. Monroe and R. R. Trainer. *Petroleum Technology*, September 1943.

Transportation Problems of the Oil Industry. By Sidney A. Swensrud. *Petroleum Technology*, July 1943.

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Chapter I. Exploration

Deeper Drilling Prospects in the Mid-Continent

By A. R. Denison,* Member A.I.M.E.

(Dallas Meeting, May 1943)

Abstract

Several productive areas in the Mid-Continent are broadly and briefly examined with respect to the present depth of drilling on productive structures, and the thickness of sediments remaining untested. Evidence is offered to show that a vertical mile to two miles of untested but prospective formation remain within reach of the drill. In no case would a well deeper than 15,000 ft. be required, and in most cases to no greater depth than 10,000 ft. Recent outstanding success of deeper prospecting in West Texas demonstrates the merits of deeper drilling on known structure.

Introduction

New fields discovered during 1942 equaled or exceeded the number in any preceding year. The total amount of oil found by these discoveries was less than in any previous year, for which accurate records are available. This means that the pools now being discovered are much smaller than in past years. This is to be expected, since the prospects available during 1942 were largely those overlooked in the earlier years and therefore represent a second or third order (in quality) of structural feature. This failure to find pools of good size and quality raises grave doubt as to the security of our future oil supply. With military needs rising almost daily, and the period of heaviest consumption in our war effort still in the future, there is even a growing doubt as to our ability to supply the amount needed for our ultimate victory. This does not mean that our reserves are inadequate, but rather that our "capacity to produce" may be inadequate. Lacking large fields with flush production, our capacity to produce is rapidly approaching our current needs. Since the industry is unable to find the large new fields necessary to keep a safe margin of "capacity to produce," other means are needed. It seems obvious that one of these should be deeper prospecting on the large, proven, productive structural features now known.

The exploratory wildcat is drilled primarily in search of a trap and the reason for failure to find oil and gas in nine out of ten cases is due to the absence of a suitable trap under the drill site. Therefore, deeper drilling on a known structural feature that is productive largely eliminates the greatest hazard in wildcat drilling. While by no means all the oil known today is found in structural traps—in fact, some have estimated that less than half is so located—the fact remains that structural traps are far more commonly the oil fields that have multiple horizons of production superimposed one over the other. Outstanding examples are the Eldorado field in Kansas, the Tonkawa and Cushing fields in Oklahoma, the Louden and Salem pools of Illinois, and the richest and most prolific of all structural traps, the Long Beach, Ventura and other similar fields of California.

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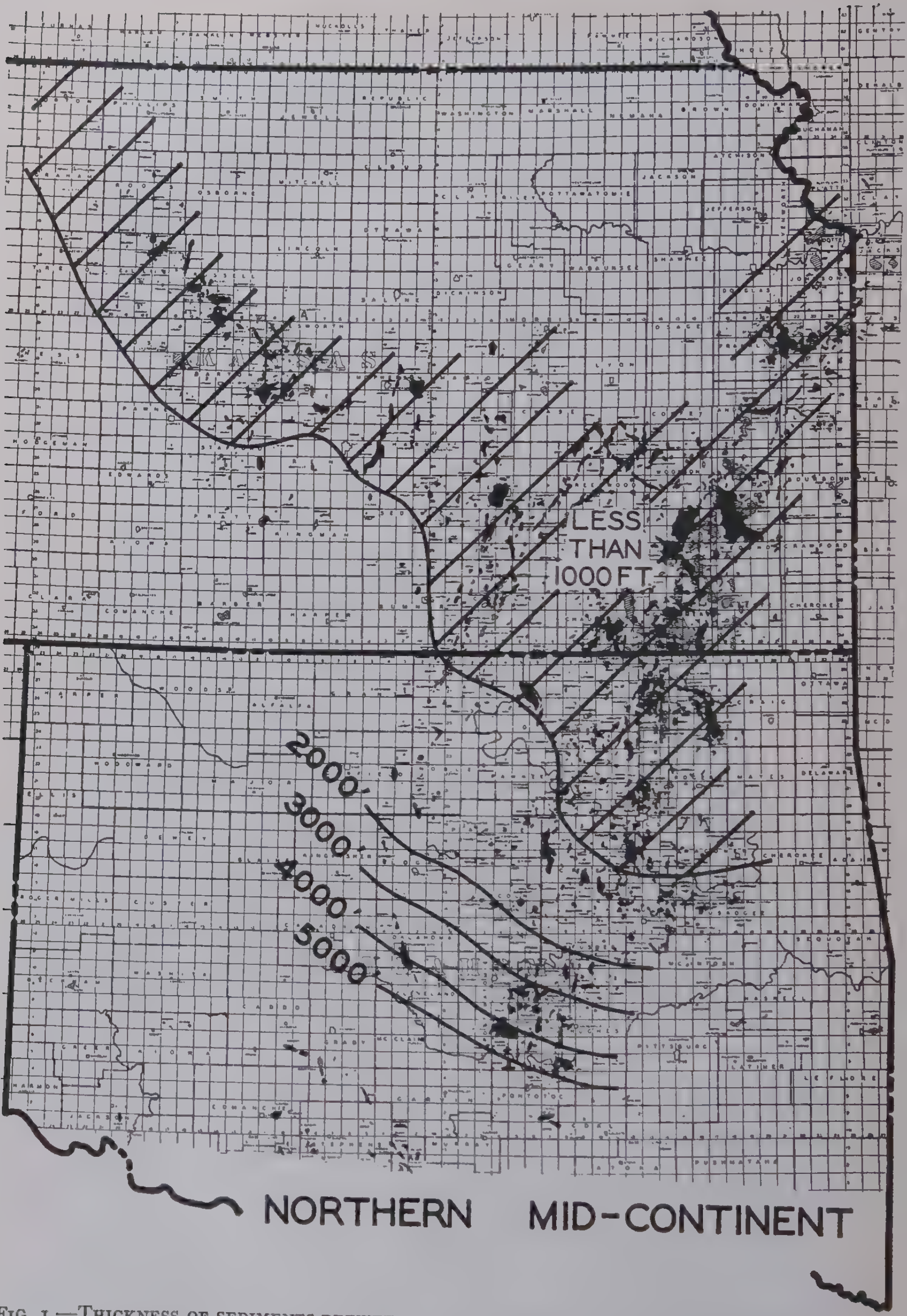

FIG. 1.—THICKNESS OF SEDIMENTS BETWEEN THE NOW GENERALLY PROSPECTED LEVELS AND THE GRANITE OR BASEMENT ROCKS IN THE NORTHERN MID-CONTINENT.

It is common in many lines of effort to overlook that which is known and near to us, in our search for that which is unknown and distant. Our productive oil fields are "known and near" and it is very easy to dismiss them with the broad generalization that they have been tested. This is true only if reliance is placed in the antiquated assumption that any given sedimentary horizon marks the end of possible oil accumulation. For many years in the early history of prospecting for oil in Oklahoma the top of the Mississippi lime was considered the "farewell" horizon. This idea was entirely eliminated by the discovery of oil in the "Wilcox" sand of Ordovician age. Other similar examples that limited prospecting could be recited for nearly every oil province.

It is assumed in this discussion that no structural trap is condemned for deeper production until all sedimentary beds above granite or other basement rocks are thoroughly prospected. There are, of course, limitations on the depth to which prospecting can go with the present design of drilling equipment, but one well has drilled below 15,000 ft. and several others have closely approached this figure. It is, then, perhaps not unreasonable to say that any known structural feature can be prospected to 15,000 ft. with the present equipment. On the following pages an examination is made of a few selected areas in the Mid-Continent to see what thickness of sediments remain between the now generally prospected levels and the basement rocks, or 15,000 ft., whichever is the shallower. In general, it will be shown that there remains not a few hundred feet but in most places more than a mile in thickness and in some more than two vertical miles of additional sedimentary beds awaiting the drill.

NORTHERN MID-CONTINENT

Fig. 1 shows the principal producing areas of Oklahoma and Kansas. The crosshatched area has in general less than 1000 ft. of sedimentary beds below present prospected horizon. This includes nearly all the productive areas of Kansas as well as the northern part of Oklahoma. In this vast area are many fine structural traps, and no doubt many of them will have deeper production; but, since the total selection to be drilled is very small, they cannot be said to have the chances of additional oil that is present in areas where the beds are many times as thick.

SEMINOLE DISTRICT, OKLAHOMA

South of this area of thin sediments, there is a progressive increase in thickness, so that under the Seminole plateau there are 4000 to 5000 ft. between the generally prospected level—the "Wilcox" sand—and the basement rocks. Fig. 2 shows the pools in the Seminole district that produce oil from purely structural traps. These fields, in the aggregate, cover more than 70 sq. miles and have produced approximately three fourths of a billion barrels of oil.

The four wells shown on Fig. 2 are the only tests anywhere on these structures that were drilled below the "Wilcox" producing horizon. Their total depths are 4478, 5080, 5181 and 6203 ft., which is 468, 760, 1541 and 1890 ft., respectively, below the producing horizon. The two deepest tests are "edge wells" in their respective fields and too low to produce in the regular pay. With more than 2500 ft. of sediments remaining above granite below the deepest of these wells, and more than 4000 ft. below the shallowest, it is obvious that they are not adequate tests of these structures.

Since the "Wilcox" sand is at an average depth of 4000 ft. in the Seminole district, and there is estimated to be 4000 ft. or more of sedimentary rocks between this depth and granite, there remains as great a thickness of sediments, or more, to be drilled than has heretofore been prospected. It would not require a well much deeper than 8000 ft. to prospect the entire sedimentary section below present producing horizons.

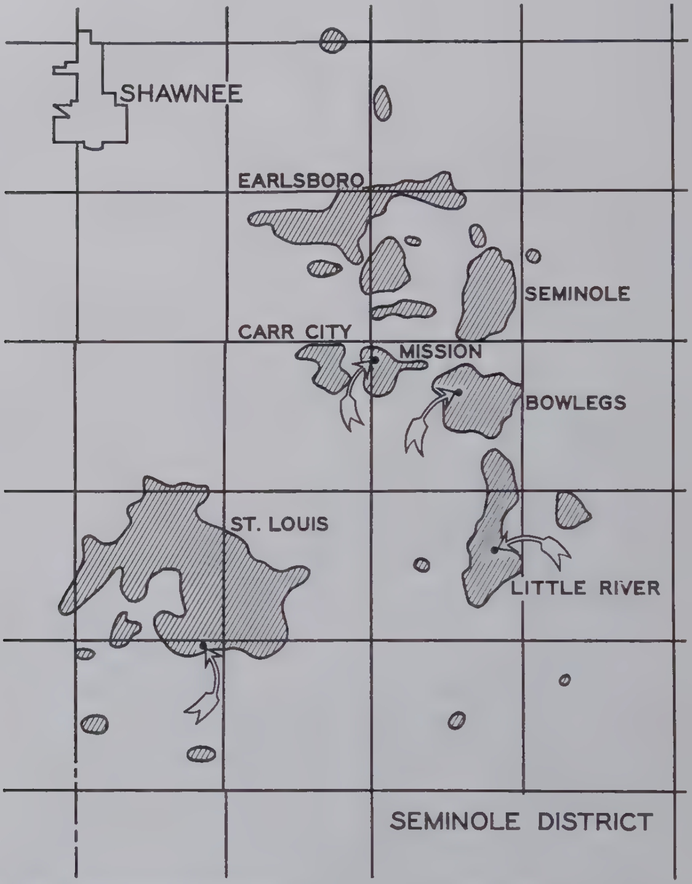

FIG. 2.—AREAS PRODUCING FROM STRUCTURAL TRAPS AND THE "DEEP" DRY HOLES IN THE SEMINOLE DISTRICT.

EAST TEXAS BASIN

In the East Texas basin, the broad structure is of such a regular nature that contour lines can be drawn to indicate the depths remaining to be prospected below the present producing horizons (Fig. 3). The numbers shown on the contours give thickness of sedimentary rocks between the Woodbine sand and (1) basement rocks, (2) and Smackover lime or (3) 15,000 ft., whichever is the shallowest. A number of fields in East Texas are producing in the Paluxy formation, and there is oil and gas-distillate production in the Glen Rose and Travis Peak, all lying below the Woodbine, but the first of these is less than 1500 ft. below the Woodbine and the Travis Peak is not more than 4000 feet.

The contour lines show ranges in thickness from 4000 at the western border to 10,000 ft. in the bottom of the basin. This deeper figure is where the Woodbine is 5000 ft. deep and thus indicates a total drilling depth of 15,000 ft. Under such outstanding structures as Van and Hawkins, there are from 8000 to 9000 ft. of untested sediments below the present Woodbine productive horizon. Under the newer Paluxy producing fields of Coke and Quitman, there are 6000 ft. or more of sediments, and at Chapel Hill, with a productive horizon at 8000 ft., there are at least 5000 ft. of sedimentary beds above the basement *and* above 13,000 ft. The fact that Woodbine structures have four or more and the Paluxy three or more known productive horizons within drilling range would appear to make such deeper drilling particularly attractive.

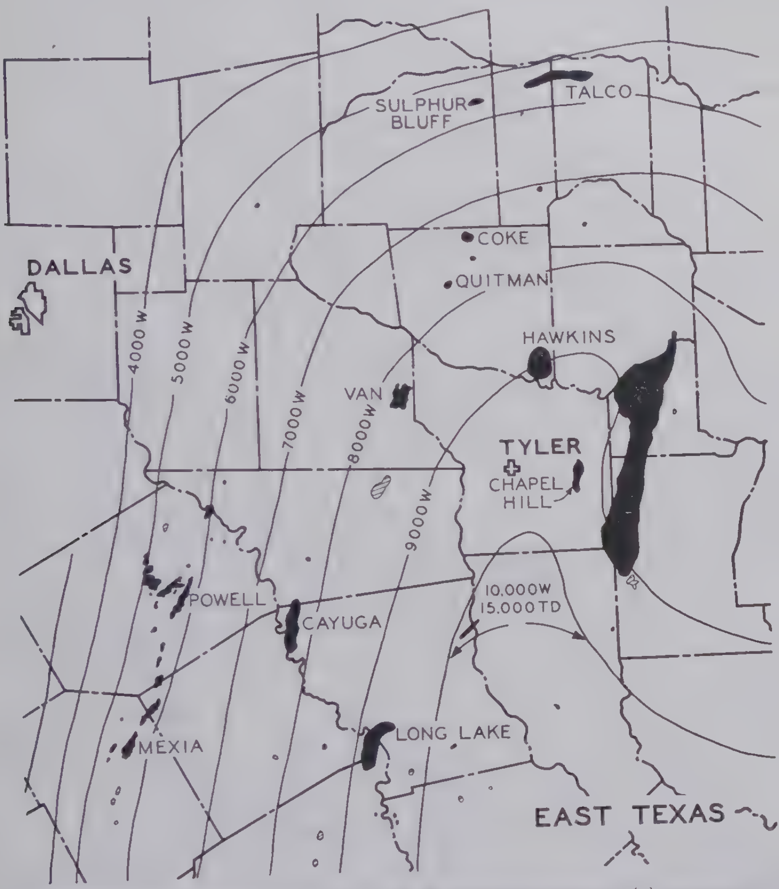

FIG. 3.—THICKNESS OF SEDIMENTS BETWEEN THE WOODBINE SAND AND (1) BASEMENT ROCKS, (2) THE SMACKOVER LIMESTONE, (3) 15,000 FEET, WHICHEVER IS SHALLOWER.

TEXAS GULF COAST

The Houston district of the Texas Gulf Coast is an area that has many outstanding oil-producing structural traps and a sedimentary column of rocks under these structures, which extends to or beyond 15,000 ft. The limits of deeper drilling, then, are there fully controlled by the capacity of the present drilling equipment. On Fig. 4 the present depth and the feet remaining to prospect are shown alongside such outstanding structures as Tomball, Conroe, Katy, Hastings, Webster, Anahuac and Hardin. The sediments still untested, and within reach of the drill, vary from 10,000 ft. at Conroe to 7300 ft. at Katy. Thus, from 1½ to 2 vertical miles of section remain to be prospected. That such drilling may "pay off" in an important way is illustrated by the Neale field, in Beauregard Parish, Louisiana. There the discovery sand was at 8000 ft. but a more prolific sand was uncovered 3000 ft. deeper. Below this deeper sand there remains more than 4000 ft. of sediments within reach of the drill.

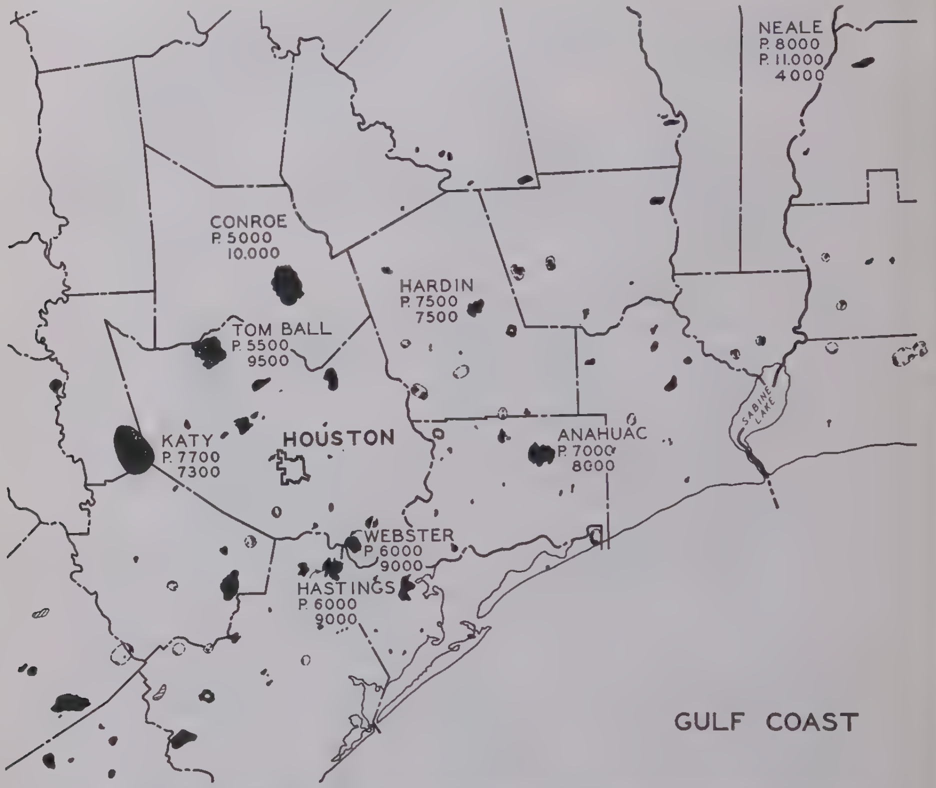

FIG. 4.—FOR A PART OF THE TEXAS GULF COAST, DEPTH OF PRESENT PRODUCTIVE ZONE (P. 7700) AND THICKNESS OF SEDIMENTS REMAINING UNTESTED ABOVE 15,000 FEET.

THE PERMIAN BASIN (WEST TEXAS-NEW MEXICO)

The Permian Basin of West Texas and New Mexico for several years following discovery of oil, produced only from the upper part of the Permian at depths ranging from 800 to 5000 ft. Ellenburger production at 8600 ft. was found at Big Lake underneath structure producing in Permian beds at 3000 ft. in 1928, but the importance of deeper drilling on proved structure, was overshadowed by the numerous prolific discoveries from the Permian. Production from Simpson and Ellenburger was discovered at the moderate depths of 5000 to 6000 ft. where the Permian was missing or barren in several fields between 1928 and 1940. At the beginning of the latter year, a trend of deeper drilling was inaugurated both for wildcat and pool wells. Some results have been deeper Permian pay at Wasson, the Embar pool of Andrews County, the Barnhart pool of

Reagan County and the Monahans pool, Ward County.

Returning, however, to the type of prospecting proved at Big Lake many years ago has led in 1943 to the discovery of the Ellenburger production at 9200 ft. at Keystone, a structure producing from the Permian at 3600 ft., and another Ellenburger discovery at 10,450 ft. in the Walton structure, producing from the Permian at 3600 ft. At both of these places more than a vertical mile of new drilling was required to reach the new productive horizon.

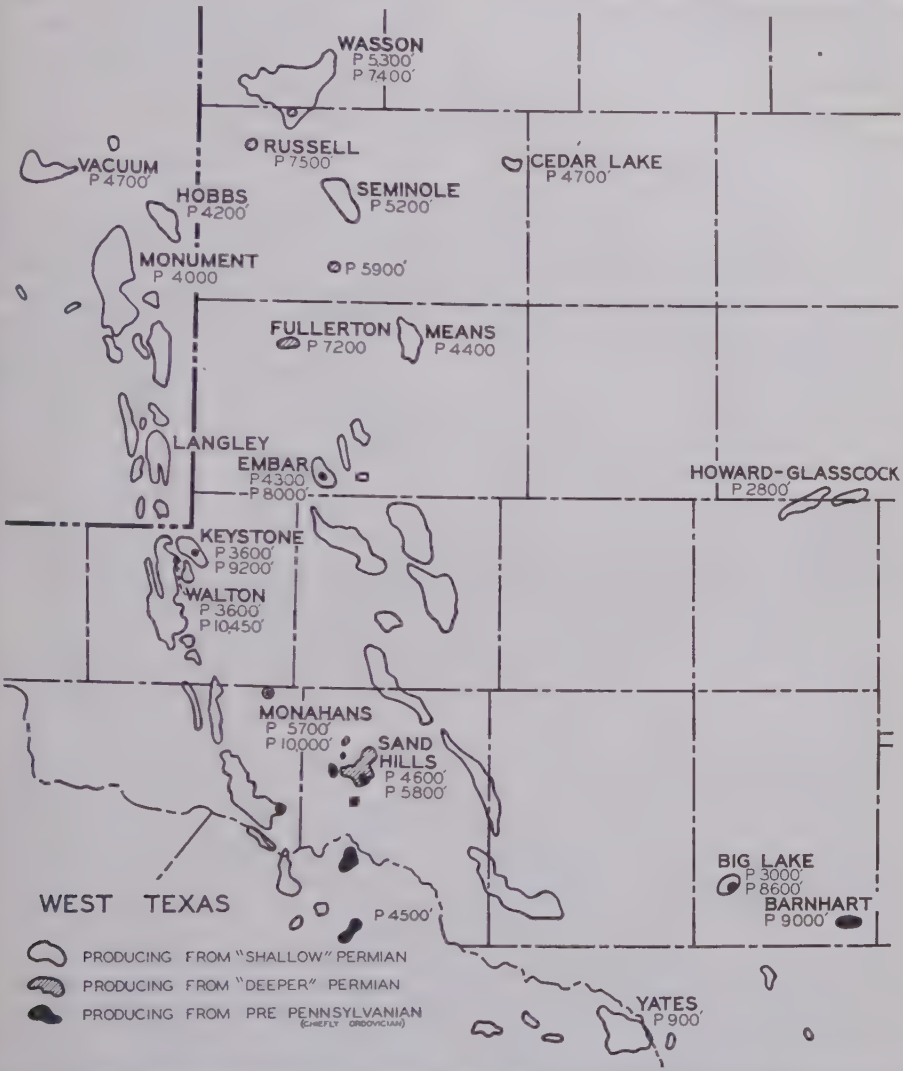

FIG. 5.—PRODUCTIVE AREAS IN SEVERAL HORIZONS AND DEPTH TO PRESENT PROSPECTED PRODUCING LEVELS IN SEVERAL OUTSTANDING STRUCTURAL TRAPS.

Outstanding structural traps such as Vacuum, Hobbs, Monument, Seminole, Means and Goldsmith have never had a test below the upper Permian. Present productive depths in these fields range from 4000 to 5200 ft., and there is ample evidence to show that a vertical mile or more of sediments remains untested under these fields. The Wasson field, producing from 5300 and 7400 ft., covers more than 70 sq. miles and has only one test that went as deep at 10,000 ft. Numerous other productive traps having less pronounced structure likewise offer good promise for deeper prospecting. There are then in Permian Basin hundreds of square miles of proved structural traps that have a vertical mile or more of sediments beneath them, which are within reach of a well drilled to 10,000 feet.

SUMMARY

In this brief examination of a few areas in the Mid-Continent, it has been shown that there is a vertical mile or more of sediments underlying in the aggregate many hundreds of square miles of structural traps. Thus, literally hundreds of cubic miles of sediments on our choicest structural features await the drill. In many places the amount of such sediments remaining is much greater than the amount already exploited. There is no need for geological or geophysical effort since structural control is available from the wells drilled thus far. A great many of them will require a well to less than 10,000 ft. and none over 15,000 ft. They all have the great advantage, in these times of material shortages, of having pipe-line and transportation facilities already available. In many places it would require little additional manpower to produce the oil thus found. Thus we have ready-made geology, depths within reach of the drill, and pipe lines and markets waiting.

With these several factors in its favor, it appears that the quickest and most certain methods of alleviating the present danger of a shortage of "capacity to produce" is deeper drilling on our known, proven, productive, structural traps.

Waters from the Frio Formation, Texas Gulf Coast

By F. W. Jessen* and F. W. Rolshausen*

(New York Meeting, February 1944)

Abstract

It is the purpose of this paper to present data on brines occurring in the Frio formation of the Texas Gulf Coast, and to show how their composition varies, (1) with depth below the surface, (2) with depth below the top of the formation, and (3) along the approximate strike.

The brines vary in chloride content from 3,180 to 73,000 p.p.m., though the average salinity of the salt waters is shown to vary with total depth; the concentration being 35,000 to 40,000 p.p.m. at 3500 to 5500 ft., slightly less than 50,000 p.p.m. chloride at 5500 to 6500 ft. and average 38,000 to 40,000 below 6500 feet.

From the analyses available, it appears that the highest concentration of salts occurs in the upper 300 ft. of the formation, while lower salinity is found with increasing depth below this point.

The salt waters from wells in Starr County show less concentration of dissolved salts than in any other group of wells farther north along the strike.

In all, 116 analyses from 63 fields and 14 wildcats, from depths ranging from 1300 to 11,400 ft. below the surface and from 2 to 3240 ft. below the top of the Frio, are recorded.

Introduction

Brines have been studied for many years in an attempt to solve some of the geologic and production problems associated with the production of oil and gas. One practical application of study of water analyses is the correlation of waters occurring above, in, or below the producing sand in the same field or throughout the same formation.

The Frio formation, the series of sands and shales occurring below the Marginulina zone and above the Vicksburg, is one of the major oil and gas-producing formations in the Texas Gulf Coast. Fossils are rare or absent in the upper Frio throughout most of the area. When available, cuttings and cores, and electric logs were used to determine the top of the Frio. A change in lithology was used to determine this point in most of the wells, and fossils were used in some of the deep wells.

It is realized that a change in lithology is not perfect for correlation purposes over long distances and some of the trends may be influenced by the inability to differentiate between the nonfossiliferous Marginulina zone and the Frio. It underlies virtually all the area shown on the accompanying map (Fig. 1). Although it is not productive in the updip facies, it has been explored to a limited degree below 12,000 ft. Furthermore, toward the coast line future drilling to deeper depths should encounter this formation.

Although thousands of wells have penetrated or drilled entirely through the formation, very few water samples have been secured from the many sands occurring in this formation and analyzed.

Previous Investigation

No previous published study has been made of the chemical composition and concentration of waters from the Frio formation. However, one water analysis

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* Humble Oil and Refining Co., Houston, Texas.

from the Frio at Buckeye has been reported by E. W. Brucks.[1] The work of Minor[7,8] at Goose Creek, Edgerley, and Hull shows a systematic increase of salinity with depth. Early recognition of the fact that local salinity anomalies might be related to structural features has been pointed out by him. Plummer and Sargent[10] reported on the waters of the Woodbine sand of the East Texas Basin and showed that the salinity of the water in the Woodbine formation increases with depth. Local salinity anomalies were found to be related to structure. W. A. Price[11] has endeavored to show the relation of shallow-water salinity and structure in the Corpus Christi area. Fash and Berger[4] indicated the rather close agreement between salinity and structure in the West Texas Basin. According to Torrey[12] some correlation exists between the age of the formation

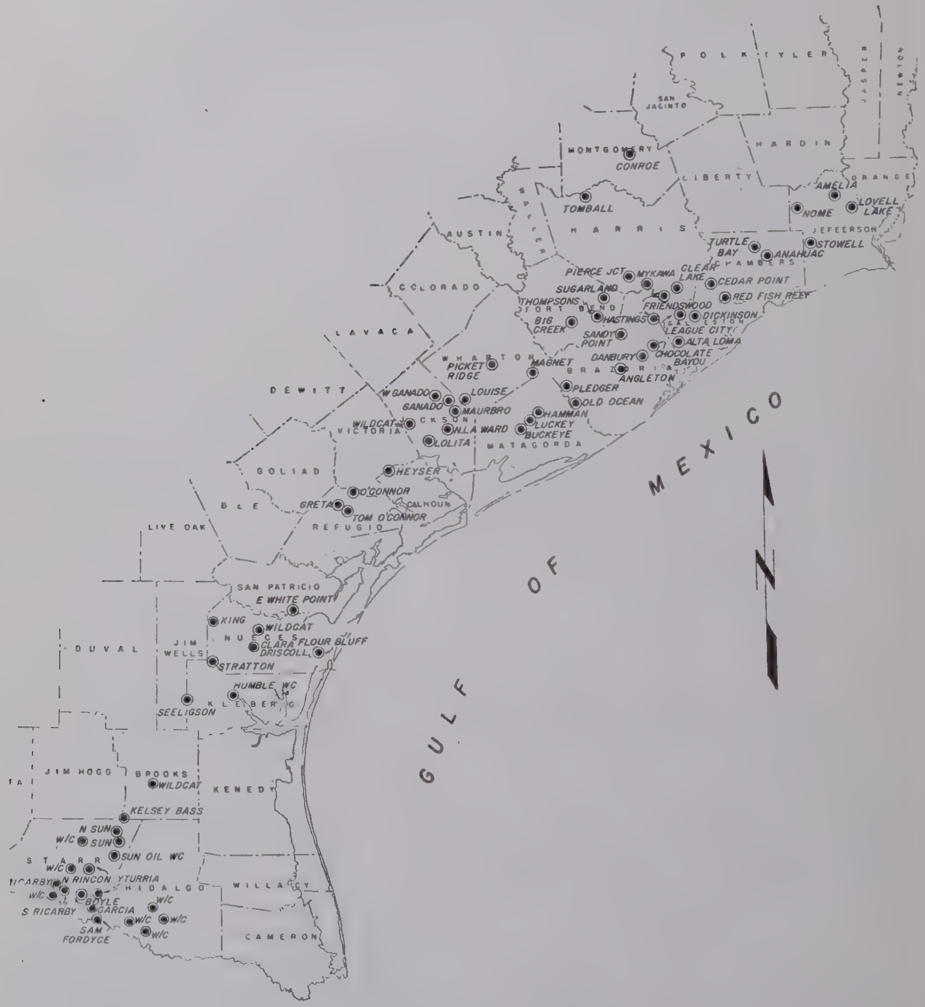

Fig. 1.—Fields of Texas Gulf Coast area from which samples were analyzed.

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[1]References are at the end of the paper.

and concentration of the dissolved solids in the waters of the Appalachian region. Case[2] found that in Oklahoma and Kansas the concentration of the brines increased with depth.

Results of This Investigation

The results of the analyses of waters from the Frio formation are presented in Table 1, which shows: (1) the name of the well and owner, (2) the county and field, (3) the depth below the surface from which the sample was obtained, (4) the top of the Frio below the surface, (5) the interval between the top of the Frio and the sampling depth, (6) the chemical composition of the water expressed in parts per million.

The values of the separate ions chloride, sulphate, bicarbonate, calcium, and magnesium have been determined experimentally, and sodium, as reported, is calculated by difference and includes any potassium present. The total solids by evaporation are not included, since the nature of the brines causes crystallization of many salts with definite amounts of water of crystallization. The total solids may be determined by addition of the separate ions.

Table 2 summarizes the chemical analyses of the various waters examined from the Gulf Coast counties indicated and includes data on the minimum and maximum values in parts per million of the different ions reported.

It is recognized that the top of the Frio as shown in Table 1 is really the first appearance of the Frio formation in the wells. In some instances, although the table shows the sample to be a certain number of feet below the top of the Frio, it actually may be several hundred feet below the top because of faulting or position on structure.

Where more than one analysis was available, a typical analysis was chosen, though wherever possible analyses of waters from different horizons of the Frio in the same field or wells were recorded.

Using the Palmer[9] classification, most of the waters are calculated to be secondary saline. A few waters calculate to be primary alkaline but it is believed that these waters are contaminated with treating chemicals. The secondary salinity is low—from 2 to 12 per cent—while the primary salinity varies from 85 to 95 per cent.

In a recent paper, Foster[5] discussed sulphate reduction and base exchange in salty ground waters in relation to the deficiency of calcium, magnesium, and sulphate that exist in them in comparison with the theoretical mixtures of sea water and fresh ground waters. Since virtually all the waters of this study show low secondary salinity, it is possible that base exchange reactions occurred either during or after deposition of the sediments. The lack of sulphate ion is an outstanding characteristic of the waters analyzed. This depletion of sulphates may be attributed to inorganic or organic reactions. Ginter[6] has discussed these reactions very thoroughly.

In following the variations in chemical composition and concentration of water from wells in Starr County to Jefferson County, some interesting features are apparent.

Fig. 2 depicts the change in concentration of chloride ion with actual depth of sample. It may be seen that a maximum value of chloride-ion concentration of approximately 50,000 p.p.m. exists at the depth interval ranging from 5500 to 6500 ft., though the majority of samples show an average value of approximately 38,000 p.p.m. of chloride. Three depth intervals, 1500 to 2500 ft., 2500 to 3500 ft. and 9500 to 10,500 ft., show relatively low concentrations of salts, though insufficient data are available to typify the results obtained.

Figs. 3 through 7 show the variations that occur in the chloride concentration

TABLE 1.—*Chemical Analyses of Frio Waters*

Well	Owner	Field	Depth, Ft.	Top of Frio, Ft.	Depth Below Top Frio, Ft.	Analysis, Parts per Million						Sample No.
						Na	Ca	Mg	Cl	SO_4	HCO_3	
STARR COUNTY												
No. 5, McKinney	Sun Oil Co.	Sun	4,128–4,133	2,550 ±	1,583	13,802	1,656	73	24,244	18	214	1
No. 1, Requenez	Sun Oil Co.	N. Sun	4,650–4,657	3,400 ±	1,257	13,819	2,444	58	25,896	53	116	2
No. 2, Vela	Sun Oil Co.	Boyle	2,579–2,590	1,600 ±	990	11,921	344	90	18,764	None	842	3
No. 1, Hall State	Sun Oil Co.	No. Rincon	3,481–3,485	2,300 ±	1,185	7,395	1,268	50	12,696	1,400	110	4
No. 1, Hall State	Sun Oil Co.	No. Rincon	4,615–4,619	2,300 ±	2,319	10,707	933	78	17,923	445	78	5
No. 1, L. Speer	Sun Oil Co.	Wildcat	5,406–5,436	2,750 ±	2,686	14,249	1,842	82	25,049	130	561	6
KLEBERG COUNTY												
No. 1, Mark	Humble	Wildcat	5,222–5,243	3,795	1,523	13,756	2,400	24	25,300	160	201	7
No. 3, King Ranch Cabeza	Humble	Seeligson	4,695	4,010	685	8,257	738	35	14,000	111	128	8
No. 7, Cabeza	Humble	Seeligson	5,692–5,697	4,023	1,676	10,634	1,590	10	19,000	54	384	9
No. 31, King Ranch Paso Ancho	Humble	Stratton	6,669	4,217	2,452	5,809	195	18	8,750	None	1,068	10
No. 1, King Ranch Arroyo	Humble	Stratton	6,176–6,221	4,274	1,947	25,551	8,168	234	54,500	None	201	11
NUECES COUNTY												
No. 1, Isensee	Texas Conservative	Wildcat	5,968–5,984	4,640	1,344	19,481	2,148	91	34,050	30	140	12
No. 1, Webb	Humble	Flour Bluff	6,680	6,440	440	25,716	1,026	241	41,700	20	805	13
SAN PATRICIO COUNTY												
No. 2, W. E. Kirk	Shell	E. White Point	5,663–5,673	5,150 ±	523	29,282	2,925	589	51,783	None	148	14
REFUGIO COUNTY												
No. 1, O'Conner	Humble	O'Conner	4,720	3,706 ±	1,014	24,402	2,345	410	42,900	None	110	15
No. 2, O'Conner	Humble	O'Conner	4,486–4,489	3,706 ±	783	24,812	2,022	253	42,500	Tr.	122	16
No. 2, O'Conner	Humble	O'Conner	4,995–5,013	3,706 ±	1,309	25,900	1,034	115	42,000	None	256	17
No. A-4, T. O'Conner	Quintana	T. O'Conner	5,015	4,850 ±	165	25,217	1,454	218	42,000	None	244	18
No. 2, F. Heard	Humble	Greta	5,459	4,475	984	27,758	626	195	44,000	None	519	19
CALHOUN COUNTY												
Welder "A" Tank Battery	Humble	Heyser	5,450	5,198	252	24,154	984	225	39,500	None	311	20

JACKSON COUNTY												
No. 1, Issacson	Humble	Wildcat	4,598–4,604	4,555	33	21,271	1,832	93	36,200	None	262	21
No. 1, Issacson	Humble	Wildcat	5,450–5,453	4,555	898	18,229	1,052	68	30,000	6	344	22
No. 4, M. Branch	Humble	Ganado	6,632–6,635	5,046	1,589	23,319	652	123	37,250	None	442	23
No. 1, Spacek	Pure	W. Ganado	5,471–5,494	4,974	520	23,290	934	232	38,000	15	488	24
No. 2, Edwards	Humble	Maurbro	5,222–5,232	5,205	37	23,616	1,314	307	39,500	None	305	25
No. B-1, Four Way Ranch	Humble	N. LaWard	5,228	5,210	18	21,598	1,680	119	38,000	None	183	26
No. A-20, L. Ranch	Humble	Lolita	6,397–6,399	5,255	1,144	25,643	900	170	41,500	12	293	27
WHARTON COUNTY												
No. 5, Cockburn	Humble	Magnet	5,535	5,489	46	30,583	2,352	376	52,000	Tr.	817	28
No. 1, Miller	Pure Oil Co.	Louise	5,808–6,820	5,145	1,685	19,957	870	109	32,400	Tr.	390	29
No. 1, Tank Battery	Texas Co.	Picket Ridge	5,500–	5,300 ±	200 ±	23,100	2,660	220	41,000	None	290	30
MATAGORDA COUNTY												
No. 1, Schmidt	Smith & McDannald	Hamman	8,207	8,124	83	34,965	4,350	450	62,800	101	98	31
No. 1, Unit	United North & South	Buckeye	7,926	7,706	220 ±	19,780	896	174	31,636	50	1,647	32
	Stanolind well head while swabbing	Lucky	8,556–8,561	7,900	661	16,968	244	59	26,053	51	1,198	33
	Stanolind from separator	Lucky	8,937–8,940	7,900	1,037	4,616	64	28	6,560	112	1,159	34
	Stanolind W.C. 1 mi. N. of field taken while swabbing	Lucky	9,400–9,404	7,900	1,300	6,424	52	51	9,042	66	1,824	35
BRAZORIA COUNTY												
No. 1, J. O. Evans	Shell	Old Ocean	10,104–10,122	8,800 ±	1,322				14,600			36
No. 1, McKinney	Shell	Old Ocean	10,122–10,138		1,338				18,100			37
No. 1, J. W. Reynolds	Shell possibly Tretolite contaminated	Old Ocean	10,103–10,124		1,324	10,750	333	21	16,450	Tr.	1,348	38
	Stanolind sample from treater dump	Old Ocean	9,721–9,732	8,800 ±	932	10,779	98	21	15,769	60	1,815	39
	Stanolind from heating treater	Old Ocean	10,132–10,142		1,342	14,155	137	64	21,276	151	1,507	40
	Stanolind from heating treater	Old Ocean	10,056–10,145		1,345	7,180	24	17	9,928	256	1,808	41
No. 1, Andrau	Phillips	Chocolate Bayou	11,407	8,850	2,557	29,170	2,244	360	49,951	37	580	42
No. C-1, Blakley	Humble	Danbury	6,610–6,625	6,522 ±	102 ±	16,625	638	112	26,500	75	976	43
No. B-1, Moller	Humble	Danbury	5,670	5,600 ±	70 ±	27,400	1,104	29	43,800	None	921	44
No. 1, Mettler	Humble	Angleton	10,578–10,585	8,905 ±	1,580	17,581	1,688	68	29,800	None	854	45
No. 16, C. Brown	Humble	Hastings	6,118	5,762	356	38,852	1,804	322	64,000	None	183	46
No. 1, M. McFarland	Humble	Pledger	6,800 ±	6,557	150 ±	6,890	253	72	10,900	None	665	47
	Stanolind separator sample	Sandy Point	6,496–6,498	6,464	34	36,262	1,808	338	59,927	69	244	48
	Stanolind Bleeder on Xmas tree	Sandy Point	6,489–6,500	6,464	36	38,899	2,005	368	64,537	37	104	49

TABLE I.—(*Continued*)

Well	Owner	Field	Depth, Ft.	Top of Frio, Ft.	Depth Below Top Frio, Ft.	Analysis, Parts per Million						Sample No.
						Na	Ca	Mg	Cl	SO_4	HCO_3	
GALVESTON COUNTY												
No. 3, Lobit	Phillips	League City	9,256–9,259	8,000 ±	1,259	39,996	2,374	486	67,012	40	453	50
No. 4, Lobit	Phillips	League City	9,117	8,016 ±	1,101	37,432	1,886	400	61,921	25	450	51
No. 1, Bayou Dev. Co.	Humble	Dickinson	9,070–9,085	7,285	1,800	20,435	512	235	32,750	None	616	52
No. 2, E. C. Wilson	Humble	Dickinson	8,029–8,033	7,640	393	27,106	2,852	496	48,100	None	488	53
No. A-19, A. Stewart	Humble	Dickinson	8,565–8,575	8,015	560	16,542	746	68	26,700	None	561	54
No. B-1, San Leon Co.	Humble	Dickinson	8,025–8,071	7,740	331	34,170	2,910	380	58,750	None	458	55
No. 1, R. B. Peters	Humble	Dickinson	8,095	7,909	184	23,783	2,288	265	41,000	None	561	56
No. 1, Fream	Humble	Dickinson	8,462–8,466	8,125	341	19,056	1,880	41	32,300	25	885	57
	Stanolind D. S. T.	Alta Loma	9,126–9,502	9,126	376 ±	17,120	418	81	26,684	103	1,089	58
	Stanolind taken while swabbing	Alta Loma	10,346–10,381	9,126	1,255	23,446	629	163	37,233	52	854	59
FORT BEND COUNTY												
No. 46, T. W. Davis	Gulf	Big Creek	3,644	3,600 ±	44	40,307	5,100	628	73,000	8	193	60
No. 47, T. W. Davis	Gulf	Big Creek	3,788	3,650 ±	138	34,856	3,480	484	61,300	3	169	61
No. 56, T. W. Davis	Gulf	Big Creek	4,126	3,700 ±	426	37,145	3,880	472	65,500	6	181	62
No. B-3, Bankers Mortgate	Humble	Sugarland	3,717	3,517 ±	200	30,980	2,781	508	54,000	None	311	63
No. B-13, Lockwood & Sharp	Humble	Thompsons	5,385	5,325	60	37,937	2,040	322	63,000	None	195	64
No. A-5, Lockwood & Sharp	Gulf	Thompsons	5,400 ±	5,300 ±	100 ±	32,700	2,280	1,160	57,784	None	122	65
HARRIS COUNTY												
No. 33, Taylor	Gulf	Pierce Junction	4,495	4,400 ±	95	27,931	4,740	1,007	54,400	None	140	66
No. 1, Manchester	Gulf	Pierce Junction	4,828	4,500 ±	328	40,600	2,552	402	67,300	None	170	67
No. 1, Vena Faris	Humble	Tomball	3,650–3,726	2,450 ±	1,276 ±	14,610	1,540	122	25,500	None	189	68
No. 6, Minnetex	Humble	Mykawa	4,873	4,837	40	39,120	1,849	303	64,400	None	116	69
No. B-38, West Fee	Humble	Friendswood	6,037–6,060	6,041	19	35,997	3,050	397	62,000	None	220	70
No. C-36, West Fee	Humble	Clear Lake	5,925	5,923	2	37,720	2,744	337	64,000	None	122	71
MONTGOMERY COUNTY												
No. 1, American Nat. Bank	Humble	Conroe	3,160	2,100 ±	1,060	2,243	32	16	3,180	20 CO_3, 60	512	72
CHAMBERS COUNTY												
No. B-1, Draught	Humble	Anahuac	7,127	7,092	35	42,472	2,608	312	71,000	Tr.	159	73
No. 2, Middleton	Humble	Anahuac	7,126	7,062	64	31,116	4,310	517	57,000	50	146	74
No. A-2, State	Humble	Red Fish Reef	9,762–9,772	8,710	1,062	37,368	1,286	220	60,100	Tr.	854	75
No. State 118, Well 1	Standard of Texas	Cedar Point	6,095 ±	5,955	140 ±	34,965	4,350	450	62,800	101	98	76
No. State 119, Well 2	Standard of Texas	Cedar Point	6,094–6,098	5,924	174	28,786	4,130	347	52,300	378	232	77
	Stanolind	Turtle Bay	6,639–6,646	6,600 ±	46 ±	25,267	1,725	483	43,261	103	171	78

JEFFERSON COUNTY

No. B-7, Steinhagen	Humble	Lovell Lake	7,788	7,693	95	11,903	426	79	19,000	62	537	79
No. 1, Failor	Humble	Lovell Lake	7,720–7,727	7,722	5	16,296	816	136	26,800	None	287	80
No. 1, Jefferson Land Co.	Humble	Lovell Lake	7,835	7,809	24	11,869	348	152	18,900	80	659	81
No. 10, Tyrell-Combest	Humble	Amelia	6,778	6,415	363	35,540	2,756	606	61,400	None	79	82
No. 1, Tyrell-Combest	Humble	Amelia	6,779	6,358	421	17,670	1,475	192	30,400	Tr.	43	83
No. 1, McCormick Fee	Humble	Amelia	6,778	6,350	428	20,290	1,568	238	34,700	None	98	84
No. 3, A. M. Carpenter	Shell	Nome	6,055	6,030 ±	25	40,100	2,835	764	69,100	11	27	85
No. 9, A. M. Carpenter	Shell	Nome	6,033–6,041	6,030 ±	25	38,232	2,970	611	65,794	103	221	86
	Stanolind	Stowell	8,519–8,523	8,500 ±	23	38,383	4,655	906	69,502	96	908	87
	Stanolind well head while swabbing	Stowell	8,823–8,826	8,500 ±	326	30,692	2,658	211	52,268	79	605	88

BROOKS COUNTY

No. 3, McGill Bros.	Humble	Kelsey Bass	4,740–4,748	3,750	990–1,000	13,502	2,460	60	25,286	32	66	89
No. 1, Boedeker	Sun Oil Co.	Wildcat	4,895–4,904	3,500	1,400	18,941	3,032	170	34,700	12	610	90

STARR COUNTY

No. 5, Chapotal	Sun Oil Co.	Yturria	3,729–3,732	1,700	2,030	14,583	455	90	23,356	37	288	91
No. 1, Yturria	Sun Oil Co.	Yturria	3,885–3,890	1,700	2,190	13,714	360	102	21,746	112	433	92
No. 7A, Chapotal	Sun Oil Co.	Yturria	3,966–3,975	1,700	2,275	15,606	480	131	24,980	78	444	93
No. B-3, Speer	Sun Oil Co.	Sun	4,932–4,933	2,535	2,400	11,008	923	98	17,839	25	1,781	94
No. 3, Coates	Sun Oil Co.	No. Rincon	4,390–4,401	2,000	2,400	14,823	801	96	24,400	37	212	95
No. 1, Coates	Sun Oil Co.	No. Rincon	4,370–4,374 4,380–4,384	2,000	1,380	6,882	192	46	10,418	362	689	96
No. 1, Hall	Sun Oil Co.	Wildcat	4,430–4,435	2,380	2,050	15,952	1,740	75	27,575	41	495	97
No. 1, Seabury	Clopton et al.	Wildcat	1,330–1,352	800 ±	530	6,631	112	66	10,123	61	770	98
No. 1A, Garcia Land & Livestock	Sun Oil Co.	Garcia	3,773–3,777	1,100	2,677	8,300	190	55	13,024	None	464	99
No. A-3, Montalvo	Sun Oil Co.	Sun	4,590–4,591½	2,550	2,040	10,351	690	87	16,750	91	1,060	100
No. C-1, Montalvo	Sun Oil Co.	No. Sun	5,330–5,334	3,150	2,184	12,938	1,096	88	21,189	None	1,647	101
No. 2, Martinez	Baldridge & Vessels	So. Ricarby	1,762–1,782	500	882	14,085	480	116	22,700	Tr.	350	102
No. 1, A. Guerra	J. L. Collins	Wildcat	6,122–6,134	2,900	3,234	15,762	1,248	112	26,527	None	538	103
No. 4, Ricarby	Moss & Heard	Ricarby	1,540–1,547	800	747	12,189	356	78	19,326	None	562	104
No. 7, DeGarza, C. L.	Sun Oil Co.	No. Sun	4,345–4,354	3,375	979	13,536	1,786	76	24,084	49	226	105
No. 1, C. L. DeGarza	Sun Oil Co.	No. Sun	5,809–5,815	3,200	2,615	22,074	4,160	274	41,983	0	368	106

NUECES COUNTY

No. B-1, Flinn	Texas Conservative Oil Co.	Clara Driscoll	4,691–4,709	4,350	359	23,237	2,090	493	40,892	None	97	107
No. 4, Brownlee	Sun Oil Co.	Richard King	5,585–5,587	3,623	1,964	3,808	6	43	5,274	109	1,122	108

HIDALGO COUNTY

No. 3-A, Sheldon	Sun Oil Co.	Sam Fordyce	2,544–2,568	1,200	1,368	10,321	95	48	16,062	83	84	109
No. 1, Daskam	Downey & Martin	Wildcat	4,090–4,115	2,350?	1,765	17,028	1,096	162	28,555	10	182	110
No. 1A, Seabury & Taylor	Fain, Inc.	Sam Fordyce	2,769–2,800	1,200	1,600	6,933	173	44	10,912	0	367	111
No. 1, G. & C. Engleman	G. & S. Exploration Co.	Wildcat	7,505	5,400	2,105	15,251	1,640	270	24,397 CO_3, 12	3,672	147	112
No. 1, Garcia	Martin & Co.	Sam Fordyce	3,085–3,105	1,200	1,905	12,048	130	47	18,470	4	809	113
No. 1A, Porter Sweeney	Sun Oil Co.	Wildcat	6,200–6,219	5,100	1,119	19,591	1,072	126	3,218	1,510	244	114
No. 1, Yturria	Homer P. Lee	Wildcat	4,008–4,024	1,800	2,224	15,548	762	126	25,578	Tr.	194	115
No. 1, Brock & Showers	S. J. Sloan	Wildcat	4,666	3,010	1,656	11,564	925	96	18,963 CO_3, 12	987	73	116

with depth below the top of the Frio formation. Total depth below surface from which samples were available varies from 1352 to 11,407 ft., whereas the interval between the sampling depth and the top of the Frio ranges from 2 to 3240 ft. In Fig. 3, analyses of waters from 16 fields and 12 wildcat wells in Starr, Brooks, Hidalgo, Jim Wells, Kleberg, and Nueces Counties are plotted; in like manner, Fig. 4 presents data from 13 fields and one wildcat in San Patricio, Refugio, Calhoun, Jackson, and Wharton Counties; Fig. 5, data from 10 fields in Matagorda, Brazoria, and Galveston Counties; Fig. 6 from nine fields in Fort Bend,

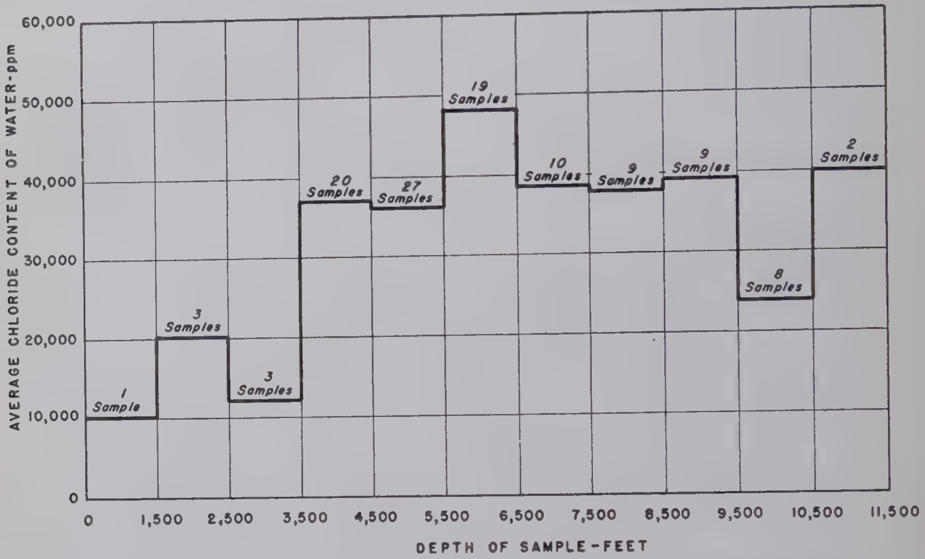

FIG. 2.—VARIATION OF AVERAGE CHLORIDE CONCENTRATION VS. DEPTH OF SAMPLE.

TABLE 2.—*Variation in Chemical Analysis of Gulf Coast Frio Waters*

County	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate
Starr	7,395–13,802	344–2,444	50–90	12,696–25,696	0–1,400	110–842
Willacy						
Hidalgo						
Jim Wells	8,257–	738–	35–	14,000–	110–	128–
Kleberg	10,634–13,756	1,590–2,400	10–24	19,000–25,300	54–160	201–384
Nueces	5,809–25,551	195–2,148	18–241	8,750–54,500	0–30	140–805
San Patricio	29,282–	2,925–	589–	–51,783	0–	148–
Aransas						
Refugio	23,284–27,758	626–2,620	175–410	40,900–45,200	0–trace	110–519
Calhoun	24,154–	984–	225–	39,500–	0–	311–
Victoria						
Jackson	18,229–25,643	652–1,832	68–307	30,000–41,500	0–27	183–488
Matagorda	17,216–	692–	243–	27,900–	0–	994–
Wharton	19,957–30,583	870–2,352	109–376	32,400–52,000	0–tr.	390–817
Fort Bend	30,980–39,600	1,705–5,100	322–1,160	54,000–73,000	0–49	122–314
Brazoria	15,620–38,852	638–1,804	29–414	24,500–64,000	0–86	183–976
Galveston	16,542–39,996	512–4,350	41–496	26,700–67,012	0–101	98–885
Harris	11,903–40,600	375–4,740	105–1,007	19,000–67,300	0–62	116–230
Montgomery	2,243	32–	16–	3,180–	20–	512–CO_3 60
Chambers	31,116–42,472	1,286–4,310	220–612	57,000–71,000	Tr.–50	146–854
Jefferson	11,869–40,100	348–2,970	79–764	18,900–69,100	0–103	27–659

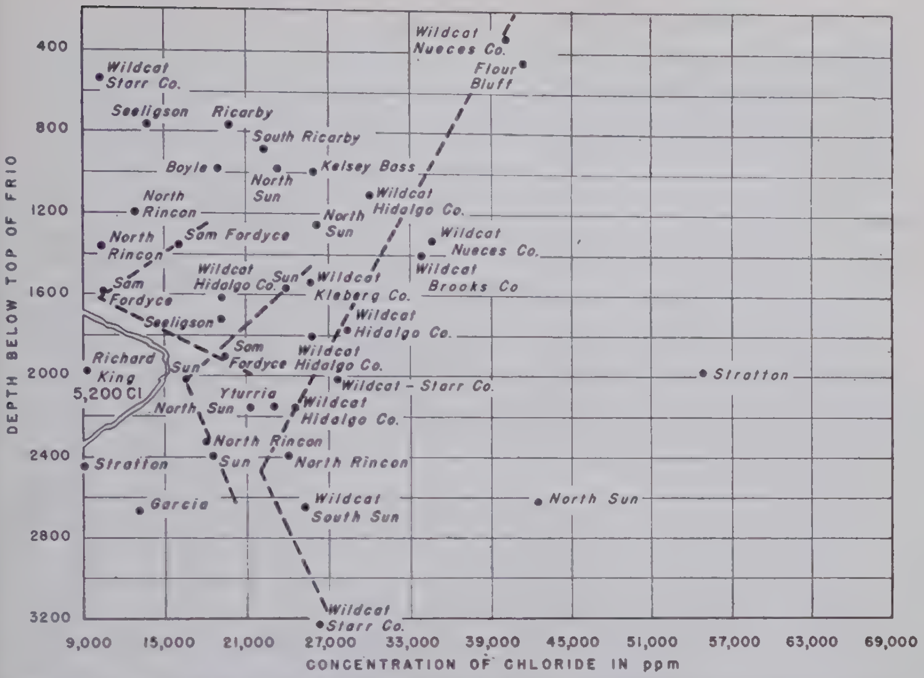

FIG. 3.—VARIATION OF CHLORIDE WITH DEPTH BELOW TOP OF FRIO IN BROOKS, HIDALGO, KLEBERG, NUECES, AND STARR COUNTIES.

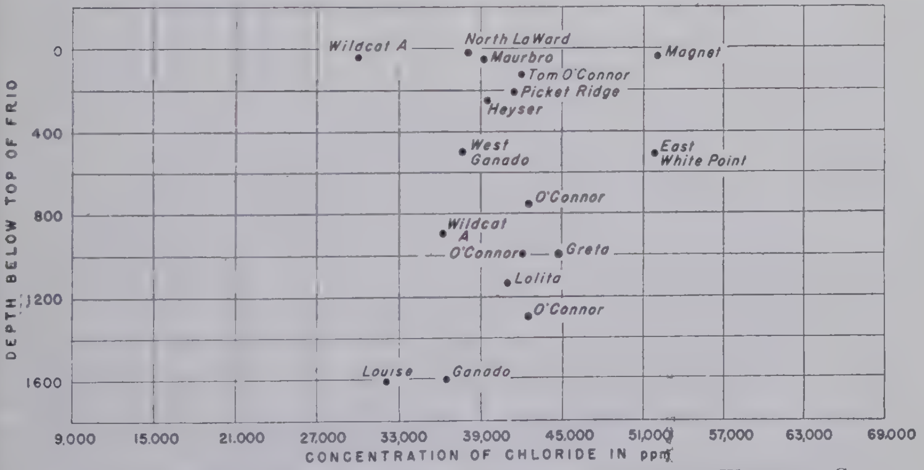

FIG. 4.—VARIATION OF CHLORIDE WITH DEPTH BELOW TOP OF FRIO IN WHARTON, CALHOUN, JACKSON, SAN PATRICIO, AND REFUGIO COUNTIES.

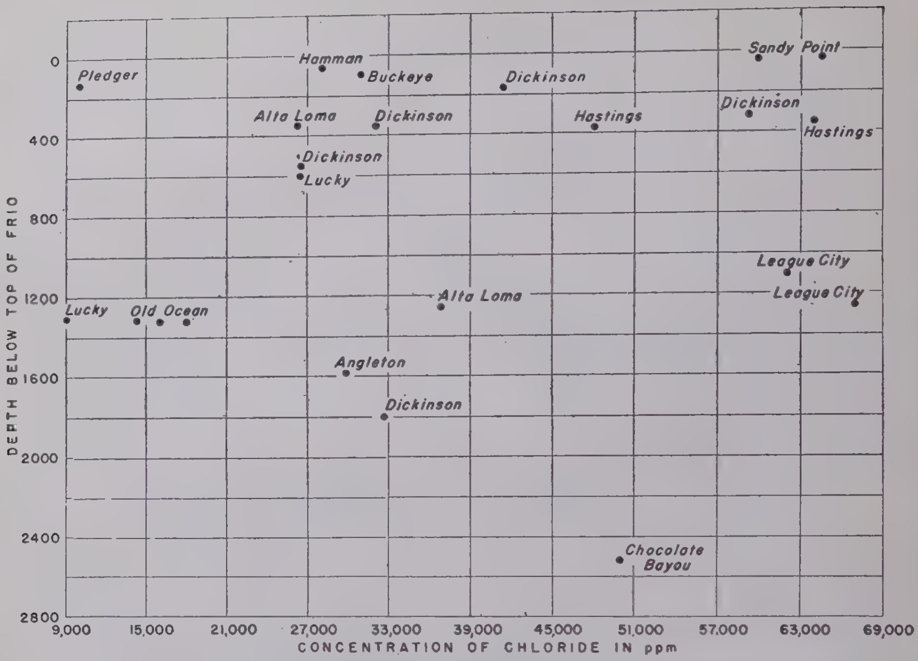

FIG. 5.—VARIATION OF CHLORIDE WITH DEPTH BELOW TOP OF FRIO IN BRAZORIA, MATAGORDA, AND GALVESTON COUNTIES.

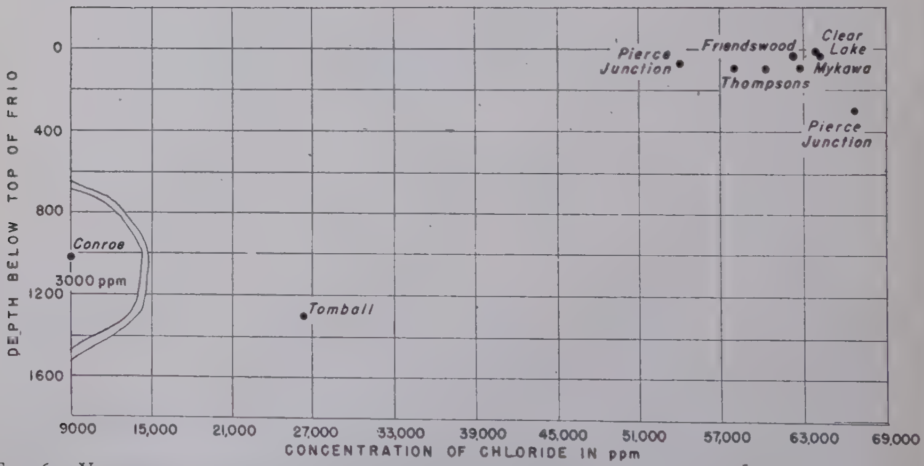

FIG. 6.—VARIATION OF CHLORIDE WITH DEPTH BELOW TOP OF FRIO IN FT. BEND, HARRIS, AND MONTGOMERY COUNTIES.

Harris, and Montgomery Counties; and Fig. 7 from eight fields in Chambers and Jefferson Counties.

The sulphate-ion concentration found in the Starr County and Hidalgo County waters is much greater than in waters from any other of which samples are available.

In the lower Rio Grande Valley area and, more particularly, in Starr County, there appear to be sufficient data available from wells in the same field and wildcat wells, producing from various depths in the Frio, to show any trends in changes of composition of the waters with depth below the top of the Frio. At first glance there seems to be no obvious definite relationship between the salt content and depth below the top of the Frio. A more critical examination by fields shows that at first there is a decrease in the total salinity, followed by increasing salinity with further penetration of the Frio. This same relationship also exists in the wildcat wells of this area. In Fig. 3 the dotted lines indicate the general change of salinity with increased penetration.

A possible explanation for this condition is the dilution of the sea water by fresh water during deposition of Frio sediments. This dilution reaches its maximum about middle Frio and then the salinity again began to increase toward the top of the section, owing to decreasing quantities of fresh water entering the sea.

Two wells, one at Conroe and one at Tomball, are the only ones from which samples were obtained from the updip facies of the basal Frio. These wells are now being used as salt-water disposal wells. The original water from the basal Frio at the Tomball salt-water disposal well is encountered at a depth below the surface of 3600 to 3800 ft., or 1275 ft. below the top of the Frio, and has a chloride concentration of 25,500 p.p.m. The water produced from the basal Frio in the salt-water disposal well at Conroe, 3040 to 3160 ft. below the surface of 1060 ft. below the top of the Frio, has a chloride content of only 3180 p.p.m. Furthermore, this water contains 20 p.p.m. of sulphate ion. This normally may be considered to be a rather low concentration, though if this water were concentrated to approximately 60,000 p.p.m. chloride, it would contain 400 p.p.m. sulphate. Only seven water analyses included in this study would have an equal or higher concentration of sulphate. Two wells in Starr County, waters from three wildcat wells in Hidalgo County, one well at Old Ocean, and one well at Cedar Point are thus characterized.

The brines from wells in Chambers and Jefferson Counties are more concentrated than those from Starr and Hidalgo Counties and are similar to the Harris County and Fort Bend County samples. One field, Lovell Lake, seems to be separate and distinct from others in this area.

Although the sampling depth, 7700 to 7800 ft. at Lovell Lake, lies between the 6000-ft. sampling depth at Nome and the 8000-ft. sampling depth at Stowell, the chloride concentration is much less at Lovell Lake than at either Nome or Stowell.

In Fig. 8 are tabulated the individual values of chloride ion determined in the 116 waters analyzed. It is evident that a trend is indicated of decreasing salinity with depth. It also shows the predominance of waters with high concentrations of dissolved salts in the upper 400 to 500 ft. of formation. Definite differences in salinity characterize the waters from Lovell Lake (No. 79, 80, 81), Conroe (No. 72), Wildcat in Hidalgo County (No. 98), Richard King (No. 108), Pledger (No. 47), and Lucky (No. 34 and 35) while the water from the salt-water disposal well at Tomball (No. 68) lies along the generalized curve.

A curve showing the distribution of samples containing less than 40,000 p.p.m. of chloride, or approximately twice the

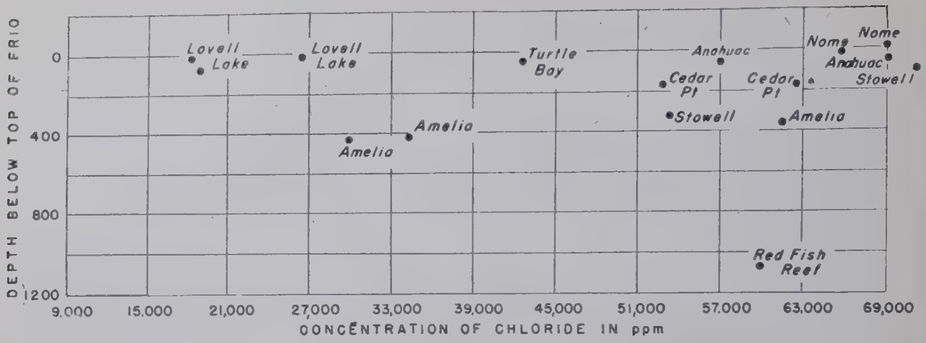

FIG. 7.—VARIATION OF CHLORIDE WITH DEPTH BELOW TOP OF FRIO IN CHAMBERS AND JEFFERSON COUNTIES.

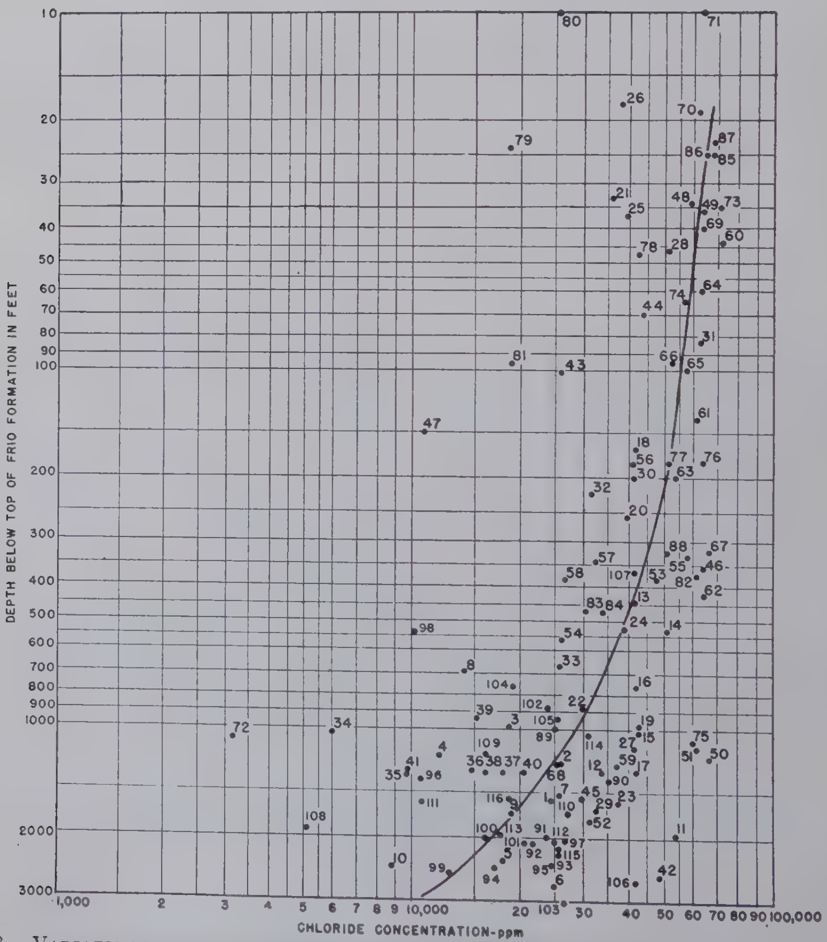

FIG. 8.—VARIATION IN CHLORIDE CONCENTRATION WITH DEPTH BELOW TOP OF FRIO FORMATION.

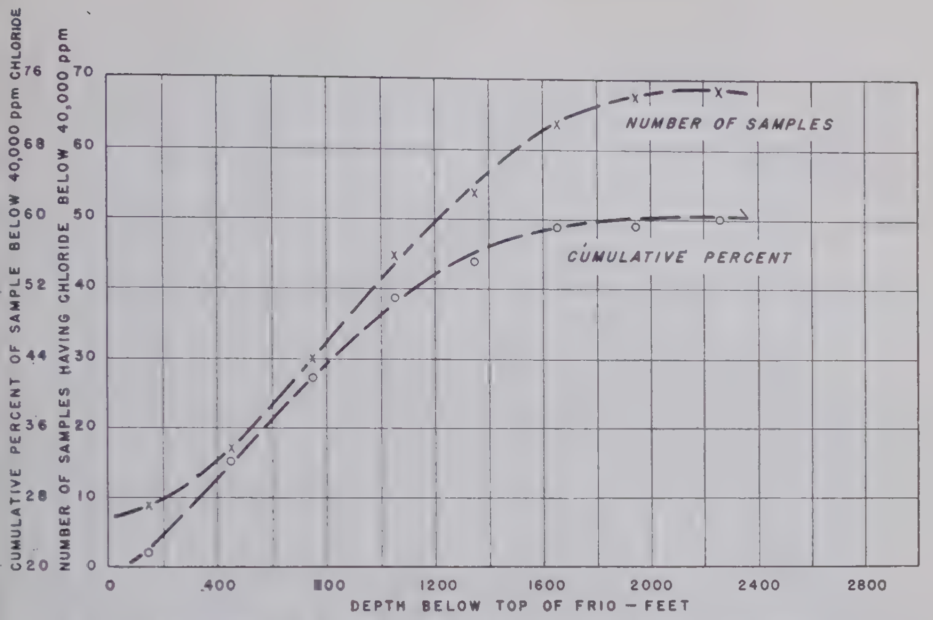

FIG. 9.—DISTRIBUTION OF SAMPLES OF WATER CONTAINING LESS THAN 40,000 PARTS PER MILLION CHLORIDE WITH REFERENCE TO ACTUAL DEPTH BELOW TOP OF FRIO FORMATION FROM WHICH SAMPLES WERE OBTAINED.

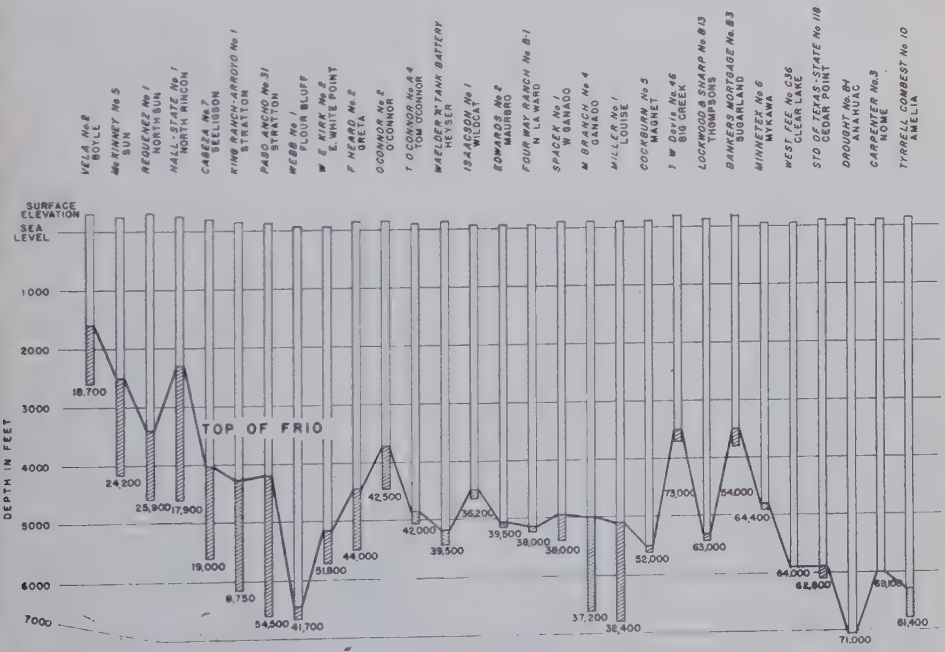

FIG. 10.—RELATIONSHIP OF SAMPLE WITH TOP OF FRIO AND CHLORIDE VARIATION ALONG APPROXIMATE STRIKE, STARR COUNTY TO JEFFERSON COUNTY.
Figures indicate chloride concentration, p.p.m.

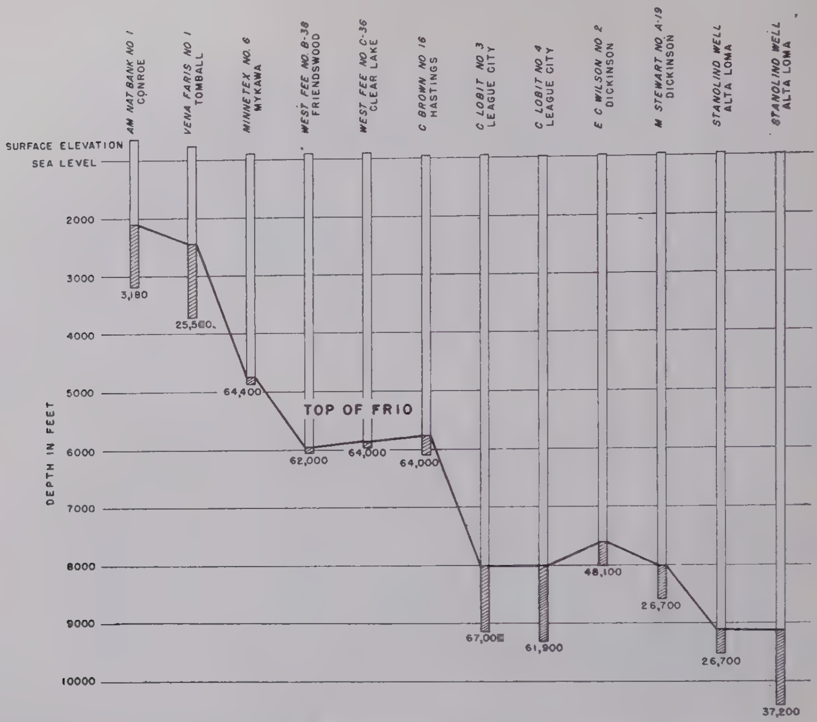

FIG. 11.—APPROXIMATE DIP SECTION, MONTGOMERY, HARRIS, BRAZORIA, GALVESTON COUNTIES. Figures indicate chloride concentration, p.p.m.

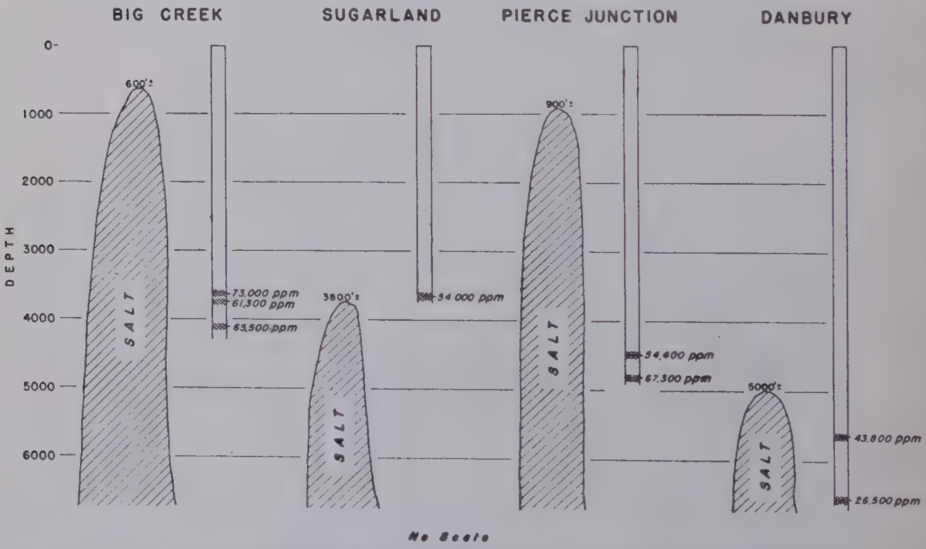

FIG. 12.—TOP OF SALT, SAMPLE DEPTH AND CHLORIDE CONCENTRATION OF WATER SAMPLES FROM FOUR PIERCEMENT-TYPE DOMES.

concentration of present day sea water,[3] is illustrated by Fig. 9. From a depth of 300 to 1500 ft. below the top of the Frio, the waters obtained yield a chloride content of more than 40,000 p.p.m., whereas below this depth the majority of waters show decreased amounts of total dissolved salts.

Fig. 10 presents the data obtained from wells approximately paralleling the present Gulf Coast shore line from Starr County to Jefferson County and shows the approximate top of the Frio, the depth of sample, and the chloride concentration. It may be seen that a considerable depth of penetration into the formation has been obtained in the several wells in Starr, Kleberg, and Nueces Counties. The remainder of the section shows much less penetration, though in Refugio and Jackson Counties some deeper samples were available. With only one exception, the highest concentration of salts occurs in the upper part of the Frio formation penetrated.

In only one area were samples available to show a partial dip section. This occurs through Montgomery, Harris, and Galveston Counties. Fig. 11 shows the depth of samples, top of the Frio formation, and chloride concentration of samples from 3160 ft. total depth to 10,400 ft. total depth. The curve shows that except for the waters from League City the maximum concentration of chloride occurs in the upper part of the Frio, and that going downdip to depths of 4500 to 6500 ft. increased salinity is observed.

Water samples are available from four piercement-type salt domes; namely, Big Creek, Sugarland, Pierce Junction, and Danbury (See Fig. 12). These waters show that the Frio sands from which the samples were obtained are not in contact with the salt. If these sands were in contact with the salt, it would be expected that much higher chloride concentrations would occur.

SUMMARY

A compilation of 116 water analyses from 63 fields and 14 wildcat wells from the Frio formation of the Texas Gulf Coast are presented. A few trends are apparent, although it is realized that additional analyses may confirm or even reverse them.

1. The chloride salinity increases and the sulphate salinity decreases from Starr County northward.

2. The chloride salinity increases with depth downdip and reaches a maximum value between 4500 and 6500 ft., and apparently decreases with depth below 6500 feet.

3. The chloride salinity seems to have a maximum value in the upper 500 ft. of the Frio and to decrease as a greater interval of the Frio formation is penetrated. This is especially evident in Harris and Fort Bend Counties.

4. No definite conclusions may be drawn from this observation, however, as to the possible relationship between this concentration of salts in the upper Frio and oil and gas accumulation, or the changes that may have been effected in the waters by contact with oil or gas, since an insufficient number of samples is available for study.

5. These waters show that the Frio sands from which the samples were obtained are not in contact with the salt. If these sands were in contact with the salt, it would be expected that much higher chloride concentrations would occur.

As previously stated, since this study was intended only to present as many data as possible on the waters from the Frio, no attempt has been made to present any solution to the practical and theoretical problems involved in the study of brines so ably summarized by Washburne and Lahee.[13]

The wide area in which only a few samples are available from numerous sands of the Frio prevents conclusive statements at this time regarding the waters. It is hoped that additional analyses of brines from the many sands of the Frio formation may become available.

ACKNOWLEDGMENTS

The authors wish to acknowledge with thanks the many analyses of waters made available to them by the J. S. Abercrombie Co., Gulf Oil Corporation, Humble Oil and Refining Co., Phillips Petroleum Co., Pure Oil Co., Shell Oil Co., Stanolind Oil and Gas Co., Sun Oil Co., Texas Company, and the United North and South Development Co. They wish to express their appreciation to the Humble Oil and Refining Co. for permission to publish this paper and also to the Division Geological Department for assistance in determining the top of the Frio.

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Natural Potentials in Sedimentary Rocks

By Parke A. Dickey,* Member A.I.M.E.

(New York Meeting, February 1943)

Abstract

Potential differences between strata of shale and sandstone have been recognized for about 15 years, and they form the basis of the electrical logging of oil wells. Hitherto these potentials have been ascribed solely to electrochemical reactions caused by the disturbing effects of the water in the drill hole through which they are generally measured. Observations by the author in wells empty of water and in a mine shaft suggest that potential differences between sandstones and shales are natural and specific properties of the rocks, although they are modified in measurement by the disturbing effects of the water in the drill hole. The cause of these potentials probably is to be sought in the relative polar adsorptive capacities of quartz and clay particles.

Introduction

The existence of potential differences in the surface of the earth has been known for some time, and their measurement has facilitated the discovery of geological discontinuities such as ore bodies. The technique of measurement has been well established.[1-3]

In measurements in oil wells, it has been found that the potential of shales with respect to some arbitrary reference is very nearly constant in any one well, at least below the zone to which meteoric water has gained access. Sandstones and some other types of sedimentary rocks have a difference of potential with respect to shale that is negative and may attain a value of 200 millivolts or more. The difference of potential, as usually measured commercially with water in the hole, is distributed over about one foot vertically at the top and bottom contacts of the sandstones. The sharpness of the curve at the formation contacts can be improved by using a short electrode that is close to the wall of the hole.

These potentials generally have been ascribed to the disturbing effects of the water in the drill hole. Potentials have been found, however, in wells in which no water was present. In the course of experiments in electrical logging in Pennsylvania, carried out by the Pennsylvania Geological Survey, observations were made of several phenomena that hitherto have not been described, to the author's knowledge, in the published literature.

The potential differences across the contacts of sandstone and shale are called in this paper "natural potentials," as distinguished from the potentials caused by electroendosmosis (electrofiltration) and concentration differences, which will be discussed subsequently.

Potentials in Cored Well

In the spring of 1942, the author measured the potentials in an exploratory well (Day 13, near Grand Valley, Pa.) which had been cored with diamond tools. The potentials were first measured with fresh water in the hole. A null balance potentiometer was used in this and all the other measurements described in this paper. One nonpolarizing porous pot electrode, containing copper sulphate solution and crystals surrounding a pure copper elec-

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* Forest Oil Corporation, Bradford, Pa.

[1] References are at the end of the paper.

trode, was lowered into the well. Measurements were made every 0.5 ft. with reference to a similar electrode on the surface near the well. On another occasion a log was made with a continuously recording instrument, but it does not show any more detail than the log made from readings at 0.5-ft. intervals.

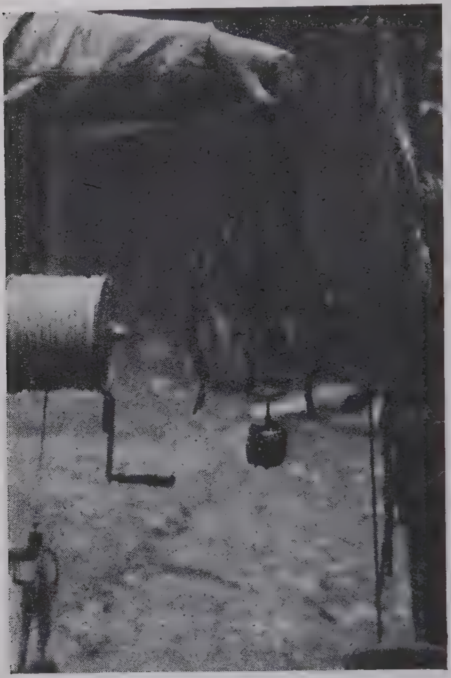


FIG. 1.—WALL CONTACTOR.

The hole was then bailed dry, and allowed to stand for several days, after which the potentials were measured in the empty hole with an improvised wall contactor (Fig. 1). This was a contrivance consisting of three legs (like umbrella ribs), which were lowered collapsed, and on reaching the bottom were tripped, so that they came out rubbing against the walls of the hole. It was made of iron with brazed joints. The legs were sheathed in rubber, and actual contact with the wall was made with a lead ball attached to one of the legs. The results were not considered satisfactory, since the metal got wet and the contact potentials were high. They were, however, reasonably constant. Readings were taken every 0.1 ft. but occasionally the lead ball would lose contact with the wall of the hole and a reading would be lost.

A comparison of the curves obtained with the hole empty and full of water is shown in Fig. 2. The empty-hole log shows a great deal more detail than the log with the hole full of water. This is to be expected, since the 6-in. column of water would have a short-circuiting and smoothing effect on the potential differences, regardless of their origin. The difference of potential between the maxima and the minima is about 25 mv. in the empty hole and 60 mv. with the hole full of water. This difference is believed to be due to the absence of the solution concentration potentials in the empty hole.

The section logged consisted of thinly interstratified hard quartzitic sandstones and shales. Some of the thicker sandstone beds contained oil, although not in commercial quantities. The curve in the empty hole was plotted on coordinate paper to 1:1 scale, and laid out along the diamond core (Fig. 3). Although observations frequently were missed, most of the sandstones (white or gray in the picture of the core) are matched by high negative values, while the shales (black) are rather constant. It seems likely that beds as thin as 0.1 ft. may be detected in empty holes.

MEASUREMENTS AT FRANKLIN SHAFT

During the summer of 1942 a shaft was sunk about 425 ft. to the Venango First oil sand at Franklin, Pa. Detailed measurements were made of three short vertical sections near the top of the oil sand, about 2 ft. apart horizontally (Fig. 4). One nonpolarizing porous pot electrode was placed at the surface, and the other was touched to the rock, the potential difference being measured with a potentiometer (Fig. 5). Referred to the surface electrode, the shales had a potential of about minus 60 mv., and the sandstones and conglomerates about minus 90 mv. The full drop of potential extended over less than 3 in., most of the gradient being concentrated within the sandstone. In the farthest right section of Fig. 4 there was a stray bed of conglomerate, ½ in. thick, separated from the main conglomerate bed by ½ in. of shale. Even this thin bed showed a negative potential of 15 mv. A curious drop of potential at the contact of conglomerate and underlying sandstone was noted, although no shale was observed at this point.

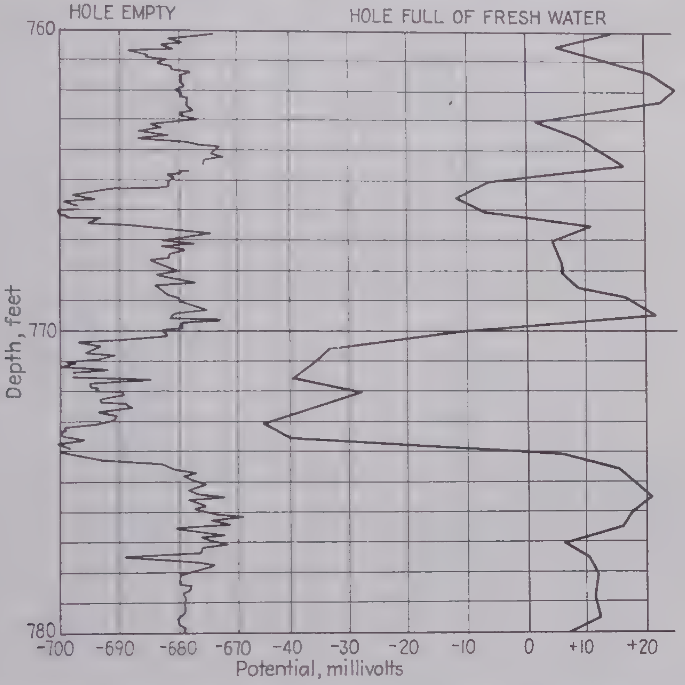


FIG. 2.—COMPARISON OF POTENTIAL CURVES OBTAINED IN HOLE FULL OF FRESH WATER AND IN EMPTY HOLE.

FIG. 3.—COMPARISON OF POTENTIAL LOG AND DIAMOND CORE.

A bed of sandstone above the oil sand, plotted in its proper position in the upper left corner of Fig. 4, contained darker

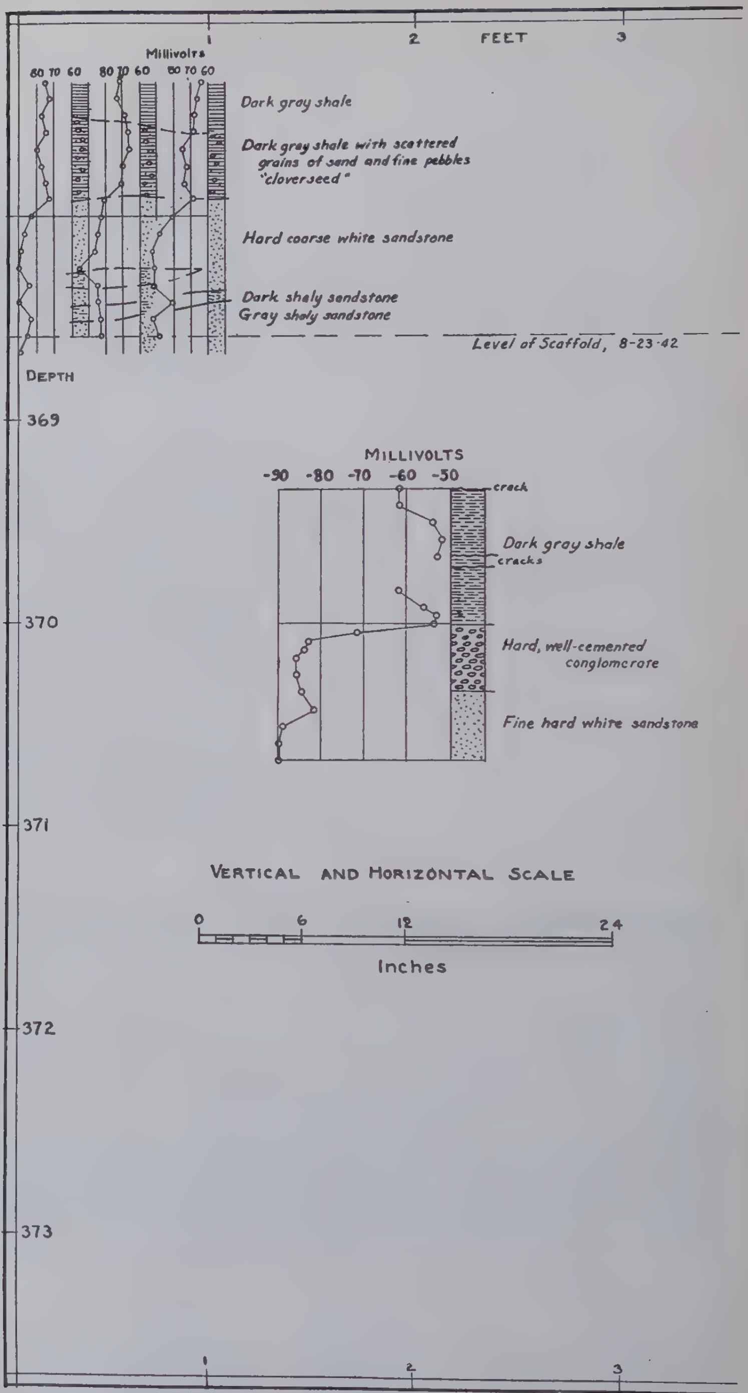
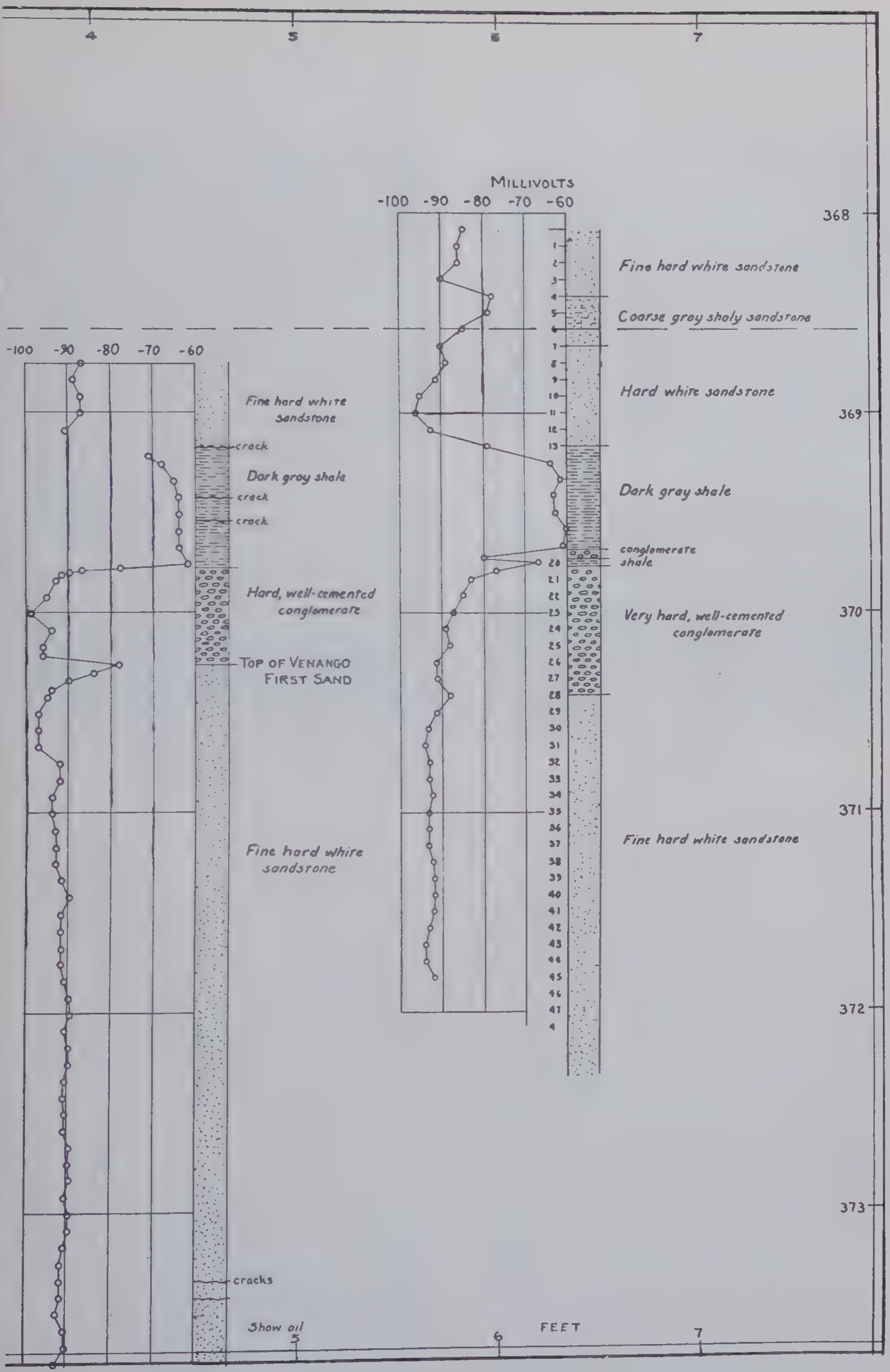


FIG. 4.—POTENTIAL LOGS



FRANKLIN MINE

streaks of shaly sandstone running irregularly through it. The potential in the shaly beds was 5 to 10 mv. lower than in the pure sandstone.

Fig. 5.—Measuring potentials in mine shaft.

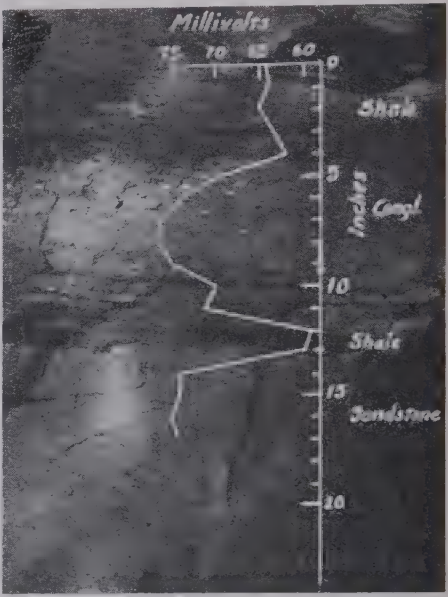


Fig. 6.—Shale, conglomerate and sandstone in Franklin shaft, showing observed electrical potentials.

Some weeks later another shale and conglomerate bed was encountered about 30 ft. below the top of the sand. The potentials in this series were measured directly below the previous measurements. It happened that this point was near the outlet of the air pipe, and air had been blown over the face of the rock for about a week prior to the measurement. Small amounts of water had condensed on it and the shale had begun to slack and crumble. The potential differences between the sand and shale were less than 2 mv. At a more recently exposed point in the same bed, about 20 ft. away horizontally, the potentials were quite sharp and had a value of about 20 mv. Fig. 6 is a photograph of this place, with the potentials plotted on the picture.

Potential measurements were also taken at the base of the sand, but no difference in potential between the sand and the underlying shale was found. The lower part of the sand contained a good deal of salt water, which, at the time the measurements were made, had been slowly seeping down over the face at the contact. It is considered probable that this salt water either short-circuited the potentials electrically or removed their cause chemically.

After making the measurements in the mine, the movable electrode was touched to numerous chunks of sandstone and shale as they lay on the dump, some of which had been exposed to the atmosphere for several weeks. Each chunk had a definite potential. As a rule the sandstones were more negative, but occasionally one was found with a positive potential with reference to an adjoining shale chunk. Three samples were measured relatively to each other, both sandstone and conglomerate being about 20 mv. positive with respect to the shale. After soaking in tap water separately for about a week, the water being changed occasionally, the potentials were unchanged.

Potential differences between sand and shale have also been noted by the author in fresh drill cores. There seems little doubt that the potential difference is a specific property of the rock and its contained electrolyte, although it may easily be changed by contact with different electrolytes.

CONTACTS OF SANDSTONES AND SHALES

From the foregoing observations the author is inclined to believe that potential discontinuities exist at the contacts of sandstones and shales, in subsurface strata that contain strong connate water. It is probable that in near-surface formations circulating meteoric waters have destroyed the uniform potential layers. If these potential discontinuities do exist permanently, a new attack on the theory of surface resistivity measurements may be required. The presence of such permanent potential layers had been suspected previous to the work described in this paper. Lee[4] in 1939 published certain observations that could be explained only on the basis of potential layers in the earth. Potential measurements in oil wells empty of water have been made for several years, although none of the results have been published, to the author's knowledge.

It is believed that potential observations in oil wells empty of water may have important practical significance in districts where great accuracy in the location of the tops and bottoms of formation is required. No satisfactory electrode has been constructed as yet. The author believes that it will have to be of the nonpolarizing type, so constructed that a positive contact of small area will be made against the wall of the hole at all times.

It is not the intention to formulate here a hypothesis to account for the natural potential differences between sandstones and shales. It seems probable, however, that the cause is related to selective adsorption by the colloidal clay particles of the ions of the connate water contained in the sedimentary rocks.

It is well known that most solids acquire a potential difference when immersed in a solution of an electrolyte. Certain substances, among them kaolin, which is chemically similar to shale, strongly adsorb the positive ion in preference to the negative ion of the electrolyte. It seems probable, therefore, that an electrolyte contained in the pores of a shale that is a strong polar adsorbent and has an enormous internal surface, might have a considerably different ionic composition from that contained in a sandstone. The phenomena involved are complex and probably would not be easy to study experimentally.

The effects of electroendosmosis and solution-concentration potentials, to which the existence of earth potentials in oil wells is generally ascribed, unquestionably also exist, and they modify the natural potentials.

SOLUTION-CONCENTRATION OR "CONCENTRATION-CELL" POTENTIALS

When two solutions of the same salt, but of different concentrations, are placed in contact, a potential difference is formed at the interface. Equations have been derived to determine the electromotive force of the cell, which depends on the relative velocities of the ions and the concentration of the solutions. The phenomenon is essentially transitory, since the solutions tend to diffuse; in fact, it is the diffusion that gives rise to the potential. This makes the potential difficult to measure even in the laboratory. It appears to be impossible to predict the effect of this phenomenon in an oil well. It could be measured only by placing one electrode in the well and another back in the rock completely isolated electrically from the well, which manifestly is impossible. Therefore it is impossible to calculate the effect of the solution concentration potential on the total potential measured.

This source of potential is very important in measurements of potentials in wells containing water. The magnitude of the potential difference between sandstone and shale in wells containing fresh water is much greater than that in wells containing salt water. Some of this diminution in magnitude may be due to a short-circuiting effect as the conductivity of the well water is increased. The potential differences are greater in wells containing fresh water than in empty holes. They did not exceed 30 mv. in the author's observations, while potentials of over 100 mv. are common in wells containing fresh water.

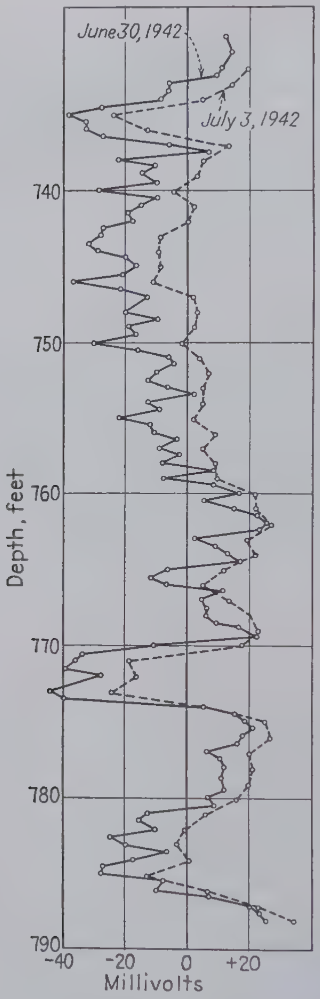


FIG. 7.—POTENTIAL LOG OF WELL DAY 13, SHOWING DETERIORATION OF AMPLITUDE AND DETAIL OF POTENTIALS AFTER FOUR DAYS WITH FRESH WATER STANDING IN HOLE.

Well Day 13 was filled with fresh water, then the potentials were measured every day for four days. They diminished notably both in amplitude and in the sharpness of their variations at lithologic changes during that period (Fig. 7). This deterioration may be due to: (1) removal by osmosis of the salts in the connate water, thereby decreasing the concentration cell potential, or (2) the removal of the cause of the natural potentials. Although this deterioration of the potentials as water was allowed to stand undisturbed on the formations has been observed frequently in Pennsylvania, it does not occur when the well is drilled with rotary tools and mud is continuously circulated past the rock. This mud forms a "filter cake," which effectively prevents the entrance of fresh water into the sandstones. Although in no case was a potential difference found in wells in which water had stood undisturbed for several months, an excellent log was obtained after cleaning out the Atlas well, near Grand Valley, Pa., that had been standing full of water for more than 70 years.[6] Apparently the motion of the water or the tools enables the sources of potential to exist. In spite of numerous attempts, the author has never been able to obtain a log of a well full of salt water from an upper horizon.

ELECTROENDOSMOSIS OR ELECTROFILTRATION

It was first observed by Reuss in 1807 that a liquid will move across a porous diaphragm under the influence of a potential difference. This phenomenon has been extensively studied since that time,[7] and has been called endosmosis or electroendosmosis. It has been found that under most circumstances when a solid is placed in contact with a liquid an electrically charged double layer is formed between the surface of the solid and the liquid. The introduction of an electrode on either side of a porous diaphragm that is negatively charged by this effect will induce a flow of liquid toward the cathode. Conversely, if the liquid is forced to move through the diaphragm by a pressure differential, an electromotive force will be produced.

Equations to relate the velocity of movement to the constants of the system and the potential gradient have been derived, but it is very doubtful whether such equations can be applied to the conditions in an oil well in order to determine how much of the total potential is due to electroendosmosis. We are dealing not with a diaphragm, but with a massive porous stratum. It is impossible to place one electrode on one side and the other on the other side of this stratum

In fresh-water strata, potential effects possibly due to electroendosmosis have been noted. In the Atlas well, mentioned above,[6] a near-surface sandstone that was known to be discharging water into the well showed a potential that was positive with respect to the shales. In an experiment performed in 1937 near Bolivar, N. Y.,[8] it was found that in a sand that had been thoroughly flushed with fresh water a higher pressure on the water in the well caused an increased negative potential opposite the permeable sand stratum that was taking the water. The well had had fresh water injected into it for several months. Potential measurements were made at various pressures of water on the sand face, and the ratio of the pressure and the product of the sand thickness and potential difference in millivolts was linear.

In the course of numerous experiments on normal wells containing oil-bearing and salt-water-bearing sands, increasing the pressure of the water in the hole did not increase the potential differences. In Pennsylvania, a relation between the potentials of the sandstones and their permeability as determined by laboratory tests and the injection of gas has been noted,[6] but this relation is believed to be due to the presence of more clay in the less permeable sandstones. Similarly, the differences in potential observed in the Franklin shaft are believed to be caused entirely by the amount of shale in the rocks and not by their relative permeabilities. The permeability of a rock is determined by the average pore diameter and pattern, which is affected by both the size of the quartz grains and the amount of shaly material. The experiments described above suggest that the potential differences, as ordinarily measured, are determined mainly by the amount of shaly material. Therefore they tend to vary with the permeability, but are not a function of the actual permeability in millidarcys. It is believed that two sands of different grain size, and therefore permeability, will show the same potential if they are equally free from shaly material. Conversely, two sands of the same permeability but of different shale content, should have different potentials.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to all those who assisted in the experiments described. In particular, he is indebted to the Venango Development Corporation for permission to make the measurements in the mine shaft, and to the J. P. Eaton Corporation for the opportunity to experiment with well Day 13.

He acknowledges much help and advice from F. W. Lee, of the U. S. Bureau of Mines, and H. Guyod, of the Halliburton Oil Well Cementing Co.

All the measurements were made with the assistance of L. S. Clough, Jr., to whom the author is greatly indebted. Robert B.

Bossler, of the Brundred Oil Corporation, made the contactor for dry-hole logging.

The writer is grateful to George H. Ashley, State Geologist, under whose direction the work was done, and to William S. Livengood, Jr., Secretary of Internal Affairs, for permission to publish this paper.

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DISCUSSION

A. C. LANE,* Cambridge, Mass.—This paper by Mr. Dickey suggests interesting observations that may well be of practical importance. I entirely agree with his conclusions that natural "potential disconformities exist at the contacts of sandstones and shales in subsurface strata that contain strong connate water." Indeed, that is shown by the way sandstone may be cemented either by pyritic deposits or carbonates just below its contact with shales. It is also true that the interstitial water itself differs in composition. Even "dry" shale and sandstone are not free from interstitial water, and the connate water may be affected by bentonitic alteration of volcanic ash or organic changes such as lead to the reduction of sulphates, but is not so likely to be affected by circulation.

He does not happen to mention limestone, but limestone and shale also may react quite differently to such an indicator as, say, methyl orange.

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* Geologist.

Natural Potentials in Well Logging

By W. D. Mounce* and W. M. Rust, Jr.,† Member A.I.M.E.

(Dallas Meeting, May 1943)

Abstract

The almost universal acceptance of electrical logging by the petroleum industry calls for a critical examination of the physical bases of the common methods. This is particularly needed for the natural potential log. The conventional explanations are based on the phenomena of electrofiltration and electro-osmosis. However, experimental data show that they fail to give a basis that is quantitatively sound. Moreover, they lead to interpretations of details of electrical logs that are erroneous.

It was found experimentally that when a plug of shale is placed in a chain of dissimilar electrolytes, a current flow results. Experiments on oil-well cores and fluids similar to those existing in wells show that potentials are set up which are in reasonable agreement with those encountered in electrical logging. Doubtless other sources of potential are important but this explanation not only accounts for much of the potential but also clarifies some fairly familiar examples of misinterpretations.

Introduction

The extraordinary value of electrical well logging as a tool for petroleum engineers and geologists is now so universally recognized that it is not necessary to point out the ways in which it can be useful. It is sufficient to mention only the saving that has resulted from the elimination of much coring that would have been necessary under former practices and the considerable additions to reserves resulting from the discovery of sands missed in coring.

Paradoxically, the very remarkable success that has resulted from the application of electrical logging to correlation and completion problems has cost some of its most consistent users dearly.[1] The fact that some operators have placed unwarranted faith in erroneous interpretations of electrical logs does not reduce the value of the logs. It should, however, make one pause long enough to ask why experienced users should be misled. The answer to this question is not hard to find. In nearly every case, the fault has been oversimplification. This is illustrated very aptly by the familiar interpretation and theory of the natural potential log.

Recording and Interpreting Logs

The natural potential log is extremely simple to record precisely enough for all present-day uses. One needs only an electrode, a cable to lower the electrode through the drilling mud, a recording meter and a surface ground connection. The electrode can be elaborate but need not be. A simple brass rod 2 in. in diameter and 2 or 3 in. long is quite satisfactory. The cable need not be particularly well insulated, nor need it have a very low resistance. The recorder can be a vacuum-tube

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* At present with the Naval Ordnance Laboratory, Washington, D. C., on leave of absence from the Humble Oil and Refining Co., Houston, Texas.

† Geophysics Research Department, Humble Oil and Refining Co., Houston, Texas. While most of the material and data for this paper were collected by the senior author, the junior author is responsible for the errors it may contain, since unavoidable circumstances made it impossible for the senior author to correct them.

[1] References are at the end of the paper.

voltmeter, an automatic potentiometer or a sensitive photographically recording galvanometer, but it can be a conventional chart-type recorder. The surface ground connection can be a stake driven into the ground, a clamp on the surface casing or an electrode placed in the slush pit.

The customary interpretation is equally simple. In many areas, such as parts of the Texas Gulf Coast, where the well encounters a series of alternate strata of sand and shale, the potential log has a familiar form. It consists of a somewhat irregular base line from which there are occasional deflections of varying amplitudes, frequently with rather sharp sides and a fairly flat top. Very frequently, the "base line" is found opposite the shale sections and the deflections or "kicks" opposite the sand sections. The interpretation is, therefore, that "kicks indicate sands" and "sands are indicated by kicks." Not infrequently, some kicks do not indicate sands. This is annoying and sometimes a little expensive but not serious and can be written off as one of nature's minor vagaries. Some people may wonder why the kicks were there but the situation is not serious. It becomes serious only when it is discovered that a sand, an oil sand, was not indicated by a kick.

THEORY

Electrofiltration Potential

The usual theory[2] is equally simple and is derived directly from the generalization that sands are somehow correlated with the potentials. The theory is twofold; that is, two concurrent causes are assigned to the potential, each adding its share to the observed total. The more popular explanation is "electrofiltration potential." Electrochemists have long been aware[3] that when an electrolyte is forced through a permeable dielectric a difference of potential is set up. This phenomenon has been studied extensively and the experimental data are public knowledge. The resulting potential is proportional to the pressure drop across the dielectric, the factor of proportionality depending upon the natures of the dielectric and the electrolyte. Since, for a given fluid and a given filter, the rate at which fluid flows through the filter is also proportional to the pressure drop across the filter, it follows that for a given electrolyte flowing through a given plug of a given dielectric, the potential due to electrofiltration is proportional to the rate of fluid flow. But for a given pressure drop, the rate of fluid flow is proportional to the permeability.

From these two fairly exact statements, it is possible by a simple non sequitur to derive the false conclusion that the potential due to electrofiltration is proportional to the permeability. Hence, if the natural potential log were principally the result of electrofiltration, it would be a permeability log; or, if only the electrofiltration potential were affected by changes in pressure, it would be possible to determine the permeability by making two logs at different pressures and observing the difference in the natural potential logs.[4]

Actually, the properties of the filter, which chiefly determine its effect on the electrofiltration potential, are its chemical nature and the condition of its surface. Its permeability has little or no effect. Any correlation between the natural potential log and permeability is to be explained by the fact that some of the factors that affect the permeability of a sand also directly affect the potential, as will be illustrated later. However, the theory that the potential log somehow measures the permeability of the sand is still popular. For this reason, it seems advisable to include some additional discussion on this point. Very direct evidence is given by the poor correlation* between potential logs in oil wells and measured permeability of cores.[5] A factor frequently overlooked in this connection is the comparison between the permeabilities of the sand and of the filter cake that is formed on the face of the sand by the drilling mud. It has been shown by experiments[6] that the permeability of the filter cake is from 100 to 10,000 times lower than the permeability of typical oil sands and almost entirely independent of the permeability of the sand; consequently, the resultant effective permeability of the sand and filter cake is determined almost entirely by the filter cake. Thus, if the potential log did measure permeability, it would be the permeability of the filter cake and not the unrelated and much greater permeability of the sand.

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* The classical example of the Bradford gas sand, Fig. 8 of ref. 4, is a log of a water-injection well where there is no filter cake on the face of the sand. Compare also Fig. 9 of this reference.

Even so, the permeability of the filter cake is higher than the permeability of the shale, so that the natural potential might be due largely to electrofiltration and thus distinguish permeable sands from impermeable sands, shales, or other materials, even though the permeability of the sand could not actually be determined. Two experiments can be cited on this point. One is a laboratory experiment;* the other, a field experiment.

In the laboratory experiment, a cylindrical core liner was placed in a radial filtration apparatus. The core was filled with a typical drilling mud and pressures ranging from 2 to 16 atmospheres were applied. The potential difference was measured between the mud being filtered and the effluent filtrate stream. Typical results were 20 millivolts for a pressure difference of 200 lb. per sq. in. It is obvious that potentials of this order will not explain the potentials of 100 mv. or more that normally are observed in logging wells. When it is realized that only a small fraction of the total electrofiltration potential will be represented by the drop in potential in the drilling mud, the discrepancy becomes even more striking.

In the field experiment, an electrode was placed opposite a sand where a large potential difference was observed. Pressure was placed on the well by means of the mud pumps. A maximum additional pressure of over 500 lb. per sq. in. was applied. This raised the pressure drop from well to reservoir to approximately three times normal and yet the potential changed by only 25 per cent. Thus, even if electrofiltration potential were the only potential that changed with pressure, it would, in this case, have accounted for less than 15 per cent of the total potential observed. Actually, nearly all electrochemical potentials vary with pressure, so that it is likely that less than 10 per cent of the observed potential resulted from the electrofiltration potential. It is then not surprising that the correlation between permeability and natural potential is poor; nor is it too remarkable that a sand sometimes fails to make itself noticeable on the potential log.

Electrochemical Potentials

What causes the other 90 per cent or so of the potential? The orthodox answer[2] is simple. The second cause is said to be another even more familiar and more thoroughly studied phenomenon—electrochemical potentials. Electrochemical potentials resulting from unlike metals in an electrolyte are everyday occurrences—in flashlight batteries, for example. Likewise, it is common knowledge that, when two different electrolytes are in contact, there is a difference in potential across the boundary. The electrolytes need not have different solutes; it is sufficient if the concentrations are different in the two electrolytes. This is the case that is familiar in oil wells where there are fresh-water and salt-water sands differing substantially in concentration. In such a case, the potential is given by a simple formula:

$$E = k \log C_1/C_2 = k(\log C_1 - \log C_2)$$

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* Performed by M. Williams, Production Research Department, Humble Oil and Refining Co., Houston, Texas.

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where E is the potential, k is a constant depending on the nature of the electrolyte and C_1 and C_2 the respective concentrations in the two electrolytes. It will be found that, for salts that commonly occur and for concentration differences that are reasonable, the potential is unlikely to be large enough to account for the potentials measured by the electrical logger. Except for this, it would seem that this is a reasonable explanation, although somewhat less satisfying than electrofiltration, since its connection with sands is less obvious.

FALLACY

Unfortunately, this simple theory has a fatal fallacy. The method used in logging is to move one electrode through the mud, which is considered to be a reasonably homogeneous electrolyte. The electrode does not cross the boundary from one electrolyte into another, so it can be affected by these potentials only indirectly. Ignoring inhomogeneities in the mud, the only way there can be a difference in potential between two points in the mud is for a current to flow in the mud; for, since the mud is a conductor, current will flow between points at different potentials. Thus, the various potential differences across the contacts between electrolytes must cause current to flow in the drilling mud if they are to affect the potential log. From the formula for the potential E due to differences in concentration, it can readily be seen that the sum of such potentials around any path, beginning and ending in the same electrolyte, must be zero. Therefore, these potentials, contrary to the popular theory, have no effect on the log. In many other cases, where the two electrolytes have different solutes, a similar equation holds for the potentials, and it can be shown in a similar fashion that they have no effect on the potential log.

CHAIN OF ELECTROLYTES

It is known that under certain conditions current will flow in a chain of electrolytes. The general conditions are not known. It is obvious, however, that, since energy is dissipated by the flow of current through materials that are not perfect conductors, energy must be supplied by some reaction occurring at or near some of the interfaces. In general, this will lead to a decrease in the potential with time. A lessening of potential has been observed sometimes when the section of a well was rerun after a lapse of considerable time.

While studying this problem, the senior author discovered one condition under which current will flow in a chain of electrolytes. This particular condition is interesting because it is one that exists in wells and because it gives a qualitative and semiquantitative explanation of some apparently abnormal logs. For example, it explains how a zone of low potential may exist in the middle of a sand, which by the conventional interpretation would indicate a tight zone, where actual tests show that the permeability is about the same as in the remainder of the sand.

This investigation was begun because of the suggestion, based on observation of logs made with nonpolarizing electrodes, that the shale zones were the seat of the phenomena largely responsible for the potentials measured in logging wells. A circular trough was divided into three sections by partitions of unglazed porcelain. These sections were then filled with three different electrolytes. Two carefully prepared nonpolarizing electrodes were placed in one of the sections. It was always found, in agreement with theory, that when the electrolytes differed only in concentration, the electrodes were at the same potential, demonstrating that no current was flowing. Similar results were obtained with many combinations of electrolytes. If clean sand cores were used as partitions, only small potentials were observed; but when shale was used for the partitions, quite large potentials were observed. Fig. 1a shows a modification of this experiment. One section is filled with shale. Section I is filled with fresh water. Section II is filled with salt water. The two sections are separated by a permeable membrane. Current flows in the direction from section I to section II. If both sections were filled with fresh or both with salt water of equal concentration, no current would flow. If section I were filled with salt water and section II were filled with fresh water, the direction of current flow would be reversed. In Fig. 1*b*, the analogous situation as it exists in a well is illustrated. If the water in the sand is more saline than the mud, current will flow from the shale into the drilling mud. Fig. 1*c* illustrates the corresponding potential log. Fig. 1*a* shows that if the mud is more saline than the water in the sand, the direction of current flow will be reversed and as a result the potential log will be reversed. A case has been observed where ordinary tannate mud was replaced by silicate mud after the well had reached a considerable depth and after preliminary

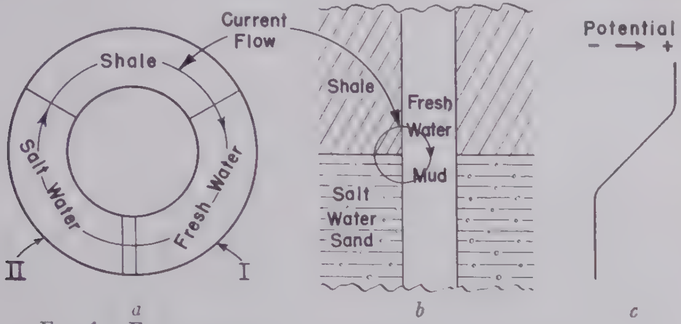

FIG. 1.—EXPERIMENTS WITH COMBINATION OF ELECTROLYTES.

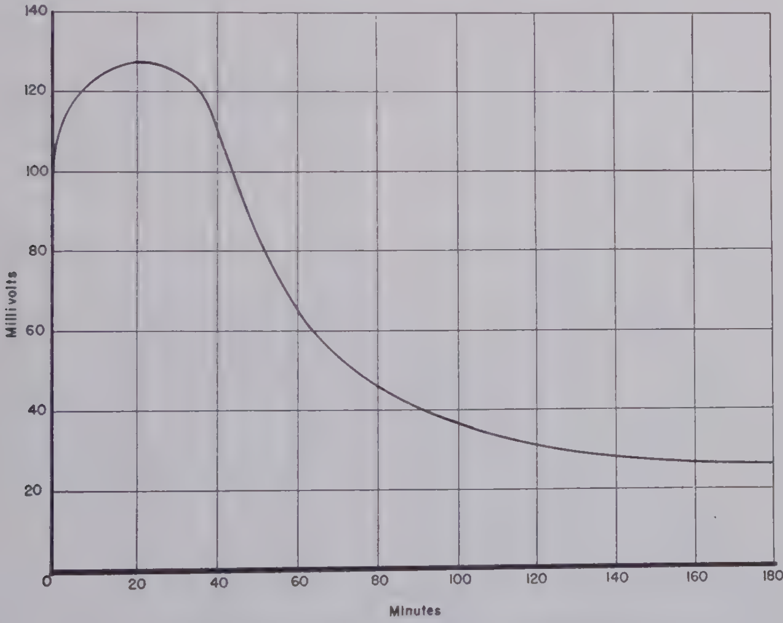

FIG. 2.—RELATION BETWEEN TIME AND ELECTROMOTIVE FORCE.

electrical logs had been made. In this instance, the potential curve was completely reversed when the hole was filled with silicate mud, giving a mirror image of the normal log. If in Fig. 1*a* the shale section is replaced by clean sand, clean porous limestone, etc., no current will flow.

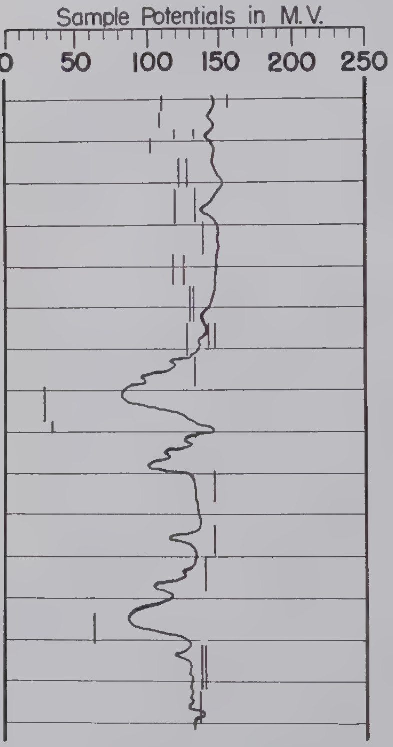

FIG. 3.—COMPARISON OF SAMPLE AND LOG POTENTIALS.

In order to obtain quantitative data, equipment was built so that the potential difference between a salt-water solution and a fresh-water solution, separated by a core, could be measured with calomel half-cell electrodes. It was found that, when the core was a clean sand, the potential difference was of the order of 5 mv.; whereas, with a shale core, the potential difference was 100 to 150 mv. with the fresh water positive. It was interesting to notice that the potential was not constant. Fig. 2 shows a curve of the relation between time and electromotive force for one such sample.

Fig. 3 shows a comparison of potentials measured for a series of cores with the electrical log made in the well from which the cores were obtained. When it is recalled that there will be some potential drop in the formation, the correspondence is rather striking.

The mechanism of this phenomenon is not clearly understood, but it does appear to shed more light on the true basis of potential logging than do the older theories. This work suggests that when fresh-water drilling mud is used, the potential log may be largely a measure of the absence of argillaceous material in the formation. This conclusion is confirmed by the observation that large "kicks" are often found opposite beds of dense limestone and that most permeable beds that do not show "kicks" are found to contain substantial amounts of shaly materials.

The utility of natural potential logs is enhanced by the fortunate circumstance that in many areas the oil and gas-producing formations are strata consisting largely of sand lying between shale or clay bodies. As a result, kicks like that shown in Fig. 1*c* are obtained at the top and bottom of the producing formation. However, it is not unusual for the sand bodies to contain considerable admixtures of shale finely disseminated in some portions or throughout the sand. In such cases, the log may suggest the presence of a tight zone, which actually is nonexistent or may fail to give sharp indications of the boundaries.

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DISCUSSION

C. A. HEILAND,* Golden, Colorado.—The authors of this article emphasize correctly that the almost universal acceptance of electrical logging by the petroleum industry calls for a critical examination of the physical bases of the common methods and that oversimplification of the processes involved has led to erroneous interpretations of electrical logs. With justifiable enthusiasm for what they believe to be a hitherto undisclosed effect, they appear, however, to have gone to the other extreme of throwing out the wheat with the chaff.

There are many cases described in the literature and in company files where electrofiltration and electrochemical effects are in the main, if not entirely, responsible for the recorded potentials. In my opinion, therefore, the authors' contention that "the conventional explanation based on electrofiltration and electrochemical phenomena fail to give a basis that is quantitatively sound," and that "the simple (diffusion potential) theory has a fatal fallacy," goes a little too far.

In the same vein, the authors take me to task for having given an "orthodox answer" to the question of the origin of electrochemical well potentials. Before refuting this statement, may I say that I do not consider myself an expert on electrical well logging, and did, in the section of my book[2] in question, confine my discussion to published accounts of theory and procedure. Most of this material has come from the Schlumberger organization, to whose work, incidentally, the authors have made no reference in their article.

My "orthodox" statement, on page 831 of my book,[2] reads as follows: "The theoretical potential difference . . . is 11.6 $\log_{10} \rho_2/\rho_1$ millivolts. However, because of an *additional* potential difference set up along the return circuits at the points *CB* and *C'B'*,* respectively, the potential difference is actually *greater* than for only one boundary. . . ." This is illustrated in the book by a figure taken from a Schlumberger publication,[7] which is virtually identical with Fig. 1*b* in Messrs. Mounce and Rust's article.

In discussing the potentials observed in wells opposite a porous sand layer embedded between two impervious argillaceous layers, Schlumberger and Leonardon have the following to say (p. 278 of ref. 7): "Laboratory experiments carried out by the authors . . . have shown that the electromotive forces *at the contacts B and C* generate a current which flows also in the direction *ACBA*, and *consequently increase* the difference of potential observed in the hole at the porous layer."

I am therefore of the opinion that the effect described by Messrs. Mounce and Rust was definitely recognized by Schlumberger and Leonardon more than ten years ago.

G. E. ARCHIE.—Regarding the electrofiltration component of the self-potential curve, I would like to list a few readings of increases in self (natural) potential opposite permeable layers due to added pressure on the mud column (Table 1). It will be seen the low values confirm those recorded by the authors.

The surveys in Table 1 were made with nonpolarizing, stable electrodes, necessary for measuring small changes in self potential accurately. Special precautions should always be taken to prevent drift of electrode potentials. In fact, if an unstable electrode is used, "kicks" that cannot be explained might be found on the log and the true self potential opposite a sand may be obliterated so that the log may be misleading. If one is to record a dependable and useful self potential, it is my experience that equipment and mud must be in first-class condition.

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* Professor of Geophysics, Colorado School of Mines.

* Point *B* is located at the interface of bore hole and shale and above the salt-water sand, point *C* at the interface of shale and sand, and the points *B'* and *C'* are at the corresponding locations below the sand. Point *A*, referred to in the next paragraph, is on the interface of salt-water sand and bore hole filled with fresh water mud.

[7] C. and M. Schlumberger and E. G. Leonardon: A New Contribution to Subsurface Studies by Means of Electrical Measurements in Drill Holes. *Trans.* A.I.M.E. (1934) **110**, 276.

Although the increase in self potential due to added pressure on the mud column is of restricted magnitude, it should not be said that the electrofiltration component will always be a small percentage of the total self potential in all wells. The electrofiltration component might be a large percentage of the total self potential when the mud filtrate has about the same dissolved salt content as the formation water, because under those conditions the electrochemical component generally will be small. This consideration, together with the data given in the table, which indicate that the increases in self potential due to pressure vary considerably from well to well, makes it difficult to say in general what percentage of the self potential is due to electrofiltration.

TABLE 1.—*Self-potential Readings*

Location	S.P. Increase, Mv. per 100 Lb. per Sq. In.	Approximate Permeability, Md.	Mud Characteristics	
			A.P.I. Filtrate Loss	Resistivity, Meter-ohms
Magnolia, Ark. (LS)	3.5	100	57	3.0
Chapel Hill, Tex. (LS)	3.0	30 Approx.	40	2.5 @ 80°F.
Lee County, Tex. (LS)	5.0	400 Approx.	25	1.7 @ 50°F.
Ward County, Tex. (LS)	3.0	1.0 to 72	60	2.1
Old Ocean, Tex. (S)	1.5	200	10	2.4 @ 75°F.
Wilson Co., Tex. (Sd)	2.5	(loose sand)	25	5.2 @ 75°F.
Jennings, La. (S)	2.0	?	15	2.9 @ 90°F.

In the discussion of the electrochemical potentials the authors have not mentioned a paper published by the Institute in 1934.[7] When referring to the electrochemical component of the self potential in a well bore, the constant K in the equation $E = K \log C_1/C_2$ is not simply a constant depending on the nature of the electrolytes C_1 and C_2, but depends also on the nature of the two rocks in contact. Therefore the formula is not quite as simple as it might appear, and the evaluation of the constant K requires actual test with natural rocks.

The text books referred to in the paper[2] as having stated that the contact of fresh mud filtrate with the salty formation water causes most of the electrochemical potential all refer to the original paper in volume 110 mentioned above, which states that the introduction of an impervious material will increase the electrochemical potential and that a current will flow in a chain composed of shale, fresh water, and salt water. In this connection, it is interesting to observe that Fig. 1*b* of Mounce and Rust is identical with Fig. 2 on page 276 in volume 110.

The authors reason that since the sum of potentials due to the contact of electrolytes in a chain or a circle is nil when beginning and ending in the same electrolyte, a liquid-liquid contact potential does not express itself on the self-potential log. If it is meant that the potential of the contact of the fresh mud filtrate with the permeable salt-water bearing formation is not registered on the log, I do not follow the authors' reasoning for: (1) no complete circuit of simple electrolytes exists in a well bore—the shale in the circuit (see Fig. 1*b*) does not act like a simple electrolyte, as demonstrated in the paper under discussion as well as in volume 110; (2) in the current path shown in Fig. 1*b* the contact *mud with salt-water sand* is traversed and is not canceled by a similar but reversed contact; i.e., *salt-water sand with mud* contact. Therefore, the potential due to the junction mud filtrate with salt-water-bearing formation in all probability affects the resultant value of this circuit.

The statement that the potential log may be largely a measure of the absence of argillaceous material is not borne out in practice. It is common to find numerous dense limestones, anhydrite, lignite and other argillaceous free, impervious material in a single well in limestone provinces in which no self potential in relation to the "shale line" is recorded. Also, it is not unusual to find no self potential opposite sandstone not containing clay in the vicinity of piercement domes when secondary cementation has filled the original pore space, making the sandstone impervious. It is my experience that where *large* "kicks" are found opposite limestones, which are considered dense because the horizon does not produce commercial quantities of fluid, *representative* cores analyzed in the laboratory show some trace of porosity and permeability.

J. M. Bugbee,* Houston, Texas.—I believe this paper will prove to be a classic. A review of the literature gives substance to this statement. The initial contribution[7] was read in February 1933, and the present work is the first addition to the theory of potential logging since then. Mounce briefly indicated in 1940, in discussion of Zaba,[1] some trends of the work that has resulted in the present essential contribution, and this research precedes that reported by Dickey in two recent papers.[8,9] Researches such as these are far from completed but already they are important in improved interpretation of logs. With resistivity logging, the initial contribution[10] was read in 1932. A theoretical consideration[11] of some effects of electrode spacing on logging values was contributed in 1936. A rigorous and comprehensive examination of resistivity logging with a point electrode and with trains of variously spaced electrodes is yet to be published. But first, the opinion should be expressed that such fundamental work should precede detailed, limited researches of the type reported by Zinszer[12] and Archie.[13]

A. C. Lane,† Cambridge, Mass.—The paper by Mounce and Rust emphasizes the fact that "there is more than one way of skinning a cat," and that variations in potential may have more than one cause. The change from permeable to impermeable is so practically important, and also so important in producing potential differences, as to tend to camouflage other factors.

W. M. Rust, Jr. (author's reply).—The authors are not familiar with the many cases in the literature referred to by Dr. Heiland, where the recorded potentials are in the main due to electrofiltration and electrochemical (when restricted to the simple diffusion potential) effects. A compilation of these logs, together with the evidence that the potentials are due only to these two effects, would be very interesting.

The work of the Schlumberger organization was not referred to in this article because the listeners to whom it was presented were already fully aware of the very important contributions of the Schlumberger organization to the art of electrical well logging. Both Dr. Heiland and Mr. Archie correctly point out the similarity between the experiments described in our paper and the Schlumberger experiments described in volume 110 of the Transactions. The difference lies in the quantitative results and, consequently, in the practical importance ascribed to the phenomenon.

Dr. Heiland italicized the words "additional" and "greater" in his discussion but not in his book. Most users of potential logs have overlooked their significance. If, in the second edition which his book has so well earned, Dr. Heiland places a corresponding emphasis upon them, the authors will feel their work has been of real service to the industry.

It should also be pointed out that the potential measured is not "the total electromotive force E_t" as stated on page 278 of the Schlumberger article, but only an unknown fraction of this electromotive force representing the potential drop due to the resulting current flowing through the resistance of the mud column.

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* Baroid Sales Division, National Lead Company.

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[10] C. and M. Schlumberger and E. G. Leonardon: Electrical Coring; a Method of Determining Bottom-hole Data by Electrical Measurements. *Trans.* A.I.M.E. (1934) **110**, 237.

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† Geologist.

Chapter II. Production Engineering and Research

Engineering Features of the Schuler Field and Unit Operation

By H. H. Kaveler,* Member A.I.M.E.

(New York Meeting, February 1943)

Abstract

A summary of the reservoir engineering and related geologic data on the Schuler field, Union County, Arkansas, is presented here in a manner intended to interest both technical and nontechnical readers.

The Cotton Valley formation and the Reynolds oölite are oil-productive formations in the Schuler field, but the Jones sand pool, at a depth of 7500 ft., developed with 146 wells on 20-acre spacing, is the reservoir of principal interest.

The Jones sand sandstone reservoir is an anticlinal trap typically gas-drive or depletion type in performance. The core analyses from 88 per cent of the wells drilled, together with drilling time and electric-log data, yield an accurate estimate of the "productive" sand thickness and its areal distribution over the pool. Accurate production statistics, monthly reservoir-pressure surveys, and bottom-hole sample analyses when correlated by the "material-balance equation" show unusually good agreement with that principle. Estimates of oil initially in place made by the material-balance method and the sand-volume method are in good agreement at 116 to 120 million barrels. The reservoir-pressure history of the pool reflects the reaction of a reservoir to production, proration and secondary-recovery practices.

The cost of the extensive program of reservoir study in the Jones sand pool has been estimated, in order to emphasize the value derived from such an investment through better understanding of a reservoir's reaction to production practices.

Unit operation of 140 of the 146 Jones sand wells made possible an effective unitized gas-injection pressure-maintenance program. Reservoir-pressure decline was arrested, natural flow was maintained, and pumping and lease equipment were conserved. An increased ultimate recovery of 20 million barrels beyond the estimated 34 million barrels primary recovery is indicated at present.

Extension of the Jones sand unit to include the undeveloped Cotton Valley formation will permit additional recovery of otherwise uneconomic reserves of oil through wells no longer required in the Jones sand operations.

Introduction

The Schuler field comprises approximately 4000 acres in and about sec. 18, T. 18 S., R. 17 W. in west central Union County, Arkansas. Three reservoirs are productive of oil and gas: the Cotton Valley formation, the Jones sand, and the Reynolds oölite section of the Smackover limestone. The Jones sand pool is the most important reservoir from an engineering viewpoint. It possesses the traditional and somewhat classic characteristics usually associated with an anticlinal trap. Development and operations have followed the dictates of advanced engineering practices. The pool has attracted attention because of the unusually detailed reservoir data obtained, its interesting production history, and the success of the unitized gas-injection pressure-maintenance operation now being carried out.

The purpose of this paper is to present a summary of the engineering data relating to the field, with particular reference to the more interesting general applications of

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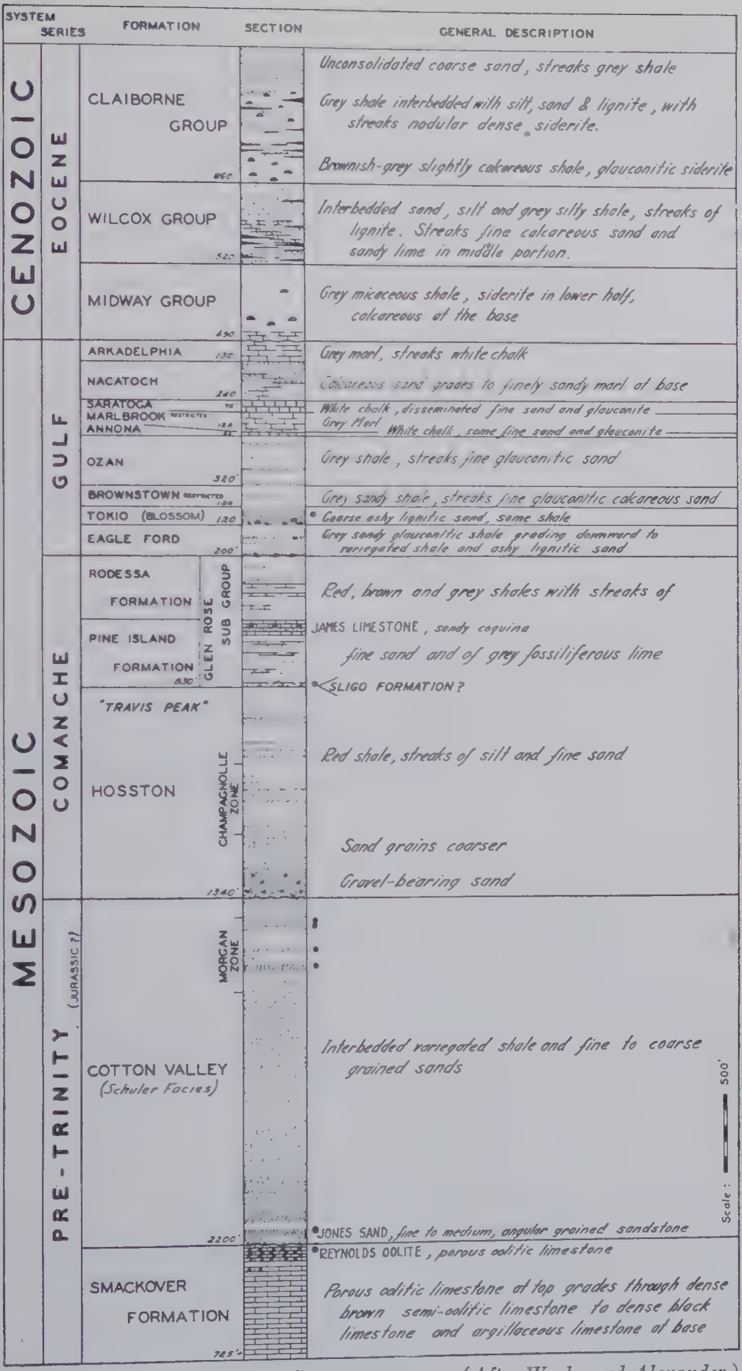
SYSTEM
SERIES
FORMATION
SECTION
GENERAL DESCRIPTION
CENOZOIC
EOCENE
CLAIBORNE GROUP
860
Unconsolidated coarse sand, streaks grey shale
Grey shale interbedded with silt, sand & lignite, with streaks nodular dense siderite.
Brownish-grey slightly calcareous shale, glauconitic siderite
WILCOX GROUP
520
Interbedded sand, silt and grey silty shale, streaks of lignite. Streaks fine calcareous sand and sandy lime in middle portion.
MIDWAY GROUP
490
Grey micaceous shale, siderite in lower half, calcareous at the base
MESOZOIC
GULF
ARKADELPHIA
130
Grey marl, streaks white chalk
NACATOCH
240
Calcareous sand grades to finely sandy marl at base
SARATOGA
75'
White chalk, disseminated fine sand and glauconite
MARLBROOK restricted
124
Grey Marl
ANNONA
31
White chalk, some fine sand and glauconite
OZAN
320'
Grey shale, streaks fine glauconitic sand
BROWNSTOWN restricted
180
Grey sandy shale, streaks fine glauconitic calcareous sand
TOKIO (BLOSSOM)
120
Coarse ashy lignitic sand, some shale
EAGLE FORD
200'
Grey sandy glauconitic shale grading downward to variegated shale and ashy lignitic sand
COMANCHE
RODESSA FORMATION
PINE ISLAND FORMATION
830'
GLEN ROSE SUB GROUP
Red, brown and grey shales with streaks of
JAMES LIMESTONE, sandy coquina
fine sand and of grey fossiliferous lime
SLIGO FORMATION?
"TRAVIS PEAK"
HOSSTON
CHAMPAGNOLLE ZONE
1340'
Red shale, streaks of silt and fine sand
Sand grains coarser
Gravel-bearing sand
PRE-TRINITY (JURASSIC ?)
MORGAN ZONE
COTTON VALLEY (Schuler Facies)
2200'
Interbedded variegated shale and fine to coarse grained sands
JONES SAND, fine to medium, angular grained sandstone
Scale: 500'
SMACKOVER FORMATION
725'+
REYNOLDS OOLITE, porous oolitic limestone
Porous oolitic limestone at top grades through dense brown semi-oolitic limestone to dense black limestone and argillaceous limestone at base

FIG. 1.—COLUMNAR SECTION, SCHULER POOL. (*After Weeks and Alexander.*)

such data to reservoir engineering phases of the Jones sand pool operations. The production history of the Jones sand reservoir is extended enough to allow at least a partial evaluation of the application of reservoir data to certain conservation practices receiving the attention of the petroleum industry.

Exploration History

The general stratigraphy of the Schuler field is shown by the generalized columnar section in Fig. 1. Unproductive wells were drilled as deep as 4385 ft. into the top of the Hosston Red Bed formation in the years 1920 to 1930. Correlations made in the course of time definitely established the presence of a long southeasterly-plunging nose in the Gulf Series formations.

Cotton Valley Production.—In April 1937, the Lion Oil Refining Co. and the Phillips Petroleum Co. drilled the Morgan 1-A well in sec. 18, T. 18 S., R. 17 W. after a seismic investigation showed favorable structure in deep beds. Oil-productive sands ("Morgan sands") were encountered at a depth of 5536 ft. about 140 ft. below the top of the Cotton Valley formation. Subsequently, 14 wells were drilled and produced from what proved to be very highly lenticular sandstones scattered throughout the Cotton Valley formation. The total depth of these wells was not more than 6000 ft. Seven dry holes drilled in the course of this development indicated poor prospects of developing an economic reserve.

Jones Sand Production.—In July 1937, E. M. Jones et al. drilled Marine Oil Co. No. 1 well in the southeast quarter of sec. 17, T. 18 S., R. 17 W. No production was found in the Morgan sand section or the remaining part of the Cotton Valley, but in drilling deeper, to test the Smackover limestone formation, a 48-ft. interval of saturated sandstone was found at 7553 to 7601 ft. The well was completed at a total depth of 7615 ft. as the discovery well of this sand—the "Jones sand." The initial potential test was 2500 bbl. per day with a small amount of water subsequently shut off by recementing.

By July 1, 1940, this sandstone reservoir had been fully developed into a major pool with 146 producing wells on 20-acre drilling units. Only three dry holes were drilled. This low percentage of failures is testimony to the value derived from careful study of the complete reservoir data obtained in the course of drilling the Jones sand.

Reynolds Oölite Production.—After the discovery well of the Morgan sand had declined in productivity to the abandonment stage, it was drilled deeper to test the Smackover limestone formation. Although the Jones sand was present in this well, a completetion was made in the upper 50 ft. of the Reynolds oölite section of the Smackover formation, on Oct. 22, 1937. The well produced gas distillate initially, and was later recompleted lower in the section as an oil well. In March 1938, an offset well was completed in the same horizon. By June 1938, the pool had been developed with 16 wells on 40-acre units.

Geology

The geology of the Schuler field has been presented in detail in an excellent recent paper by Weeks and Alexander.[1] Their work has been drawn upon freely for the geologic interpretations bearing upon this discussion.

Cotton Valley.—In the development of the Jones sand pool, oil and gas-bearing sandstone lenses were found throughout the Cotton Valley formation beyond the area and depth of the original "Morgan sand" wells. These sandstones are fine to coarse-grained, interbedded in variegated shale. They have no structural character, and the petroleum accumulations are due entirely to shale enclosure of lenses, which vary greatly in thickness, areal extent, and petroleum content. Water-oil contacts vary widely. The same is true of the free-

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[1] References are at the end of the paper.

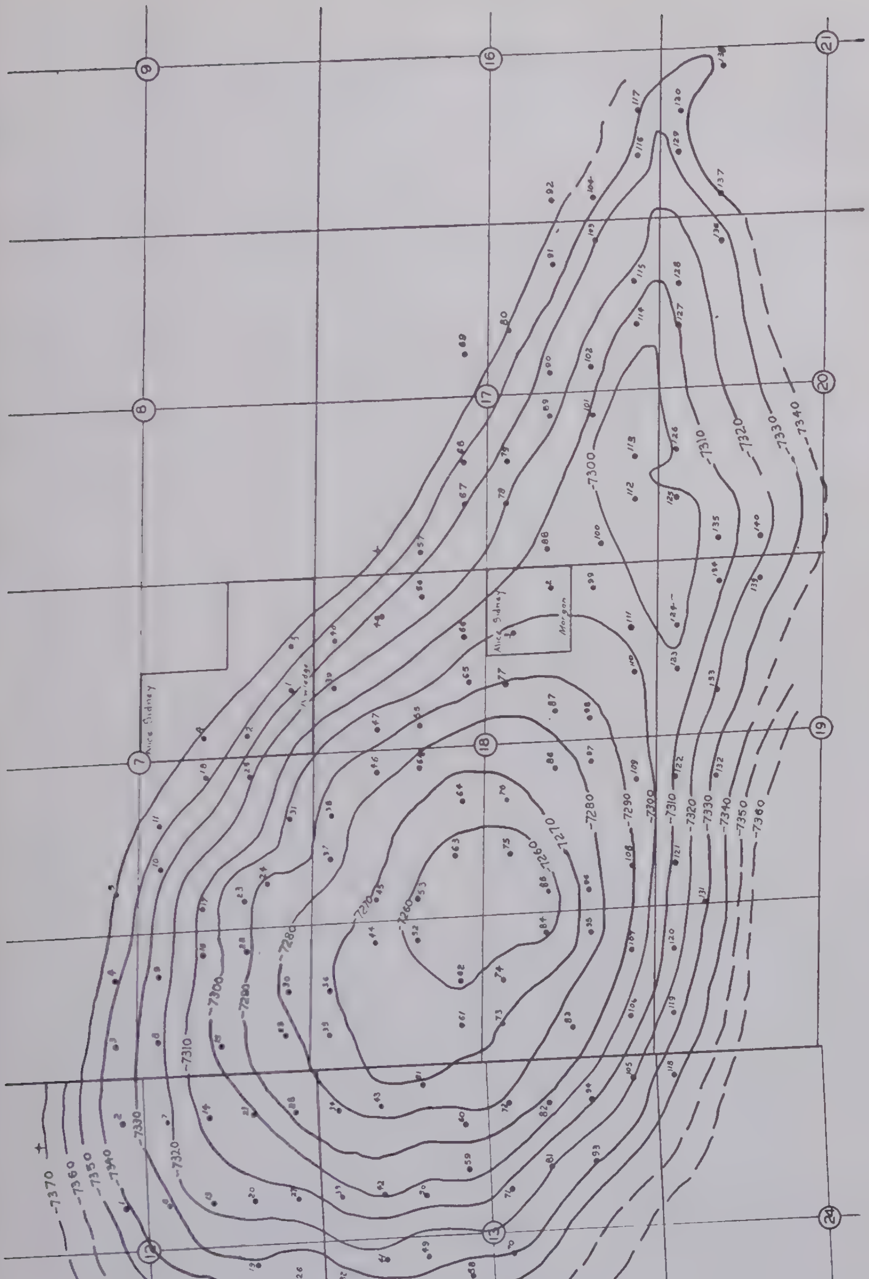


FIG. 2.—STRUCTURAL CONTOURS, JONES SAND POOL, SCHULER FIELD.

gas content, and gas-oil contacts. A few of the lenses are low-content gas-distillate reservoirs.

The average porosity of the sandstones is 16 per cent. The average specific permeabilities are in the range of 500 to 1000 millidarcys.

In general, the Cotton Valley sandstones must be classified as uneconomic sources of petroleum at Schuler as far as their direct development is concerned. The productive lenses are difficult to find, and their aggregate thickness usually is not more than 30 ft. in wells drilled through the section to date. Productive lenses vary in thickness up to a maximum of 20 ft.

Jones Sand.—The Schuler field lies within the southern limit of deposition of the Buckner red shale and anhydrite, which lies conformably above the Smackover limestone in other near-by areas of South Arkansas. Yet the Buckner formation is absent at Schuler, and the Jones sand at the base of the Cotton Valley is found immediately above the Smackover formation. Weeks and Alexander[1] are of the opinion that the Buckner was eroded away after being exposed by marked structural movement before Cotton Valley deposition. They also recognize the possibility of nondeposition, or that the Jones sand might be the Buckner equivalent at Schuler.

The Jones sand is the shallowest mappable horizon in the field showing marked structural closure. Fig. 2 shows the structural contours on the top of the sandstone. The minimum closure is 90 ft. with at least 135 ft. indicated. The angular sand grains of the sandstone vary in texture from fine to medium size. Toward the base and near the edge of the oil-saturated section, the sandstone carries silt and asphaltic residues. In addition, a general thinning of the permeable section takes place toward the east and around the flank of the structure. These observations are important in that they suggest isolation of the petroleum-bearing section from a large water-bearing reservoir, either by the limited areal extent of the reservoir itself or lack of permeability of the water-bearing sandstone.

A small initial gas cap was found in the Jones sand, occupying about 2.9 per cent of the oil and gas-saturated pore volume. The initial gas-oil contact was fixed at 7270 ft. subsea and the water-oil contact varied slightly with an average depth of 7370 to 7380 ft. subsea.

Reynolds Oölite.—The oölite zone of porosity in the upper part of the Smackover limestone formation is the deepest producing section at Schuler. Dense cryptocrystalline limestone forms a cap rock varying in thickness from 2 to 3 ft. in the southeast to 15 ft. in the northwest area. The variable thickness of the cap rock topped by a veneer of gravel is evidence of an erosional truncation of the Smackover high, which may account for the absence of the Buckner formation and the resulting unconformity of the Smackover against the Jones sand and associated Cotton Valley formation (Fig. 1).

A structural contour map on top of the Reynolds porosity is shown in Fig. 3. The porous section consists of typical concentrically grown spherical oölites ranging in size from fine to coarse. The porosity ranges up to 23 per cent, with an average near 16.7 per cent. The specific permeability of the porous section shows wide variation, although within any stratum the horizontal and vertical permeabilities are nearly equal. Some strata have specific permeabilities as high as 15,000 millidarcys. The average for the section is about 1200 millidarcys.

An initial gas cap was present, occupying about 2780 acre-feet of formation above the gas-oil contact at 7394 ft. subsea. The initially oil-saturated section above the water-oil contact at 7420 ft. subsea contained about 25,800 acre-feet.

General.—A generalized cross section of the Jones sand and Reynolds oölite prepared by Weeks and Alexander[1] (Fig. 4) summarizes structural relationships and several points of later interest.

The Smackover limestone formation possesses two structural highs within the productive area of the Jones sand pool. But the secondary high to the east carried no oil or gas saturation even though the porous oölite lay above the water-oil contact of the productive high on the west. The thin cap rock over the Reynolds oölite in the east area leads to the speculation that in the remote past migration from the Smackover limestone into the Jones sand may have occurred. In fact, one well in this area encountered no detectable thickness of dense limestone above the oölite. The

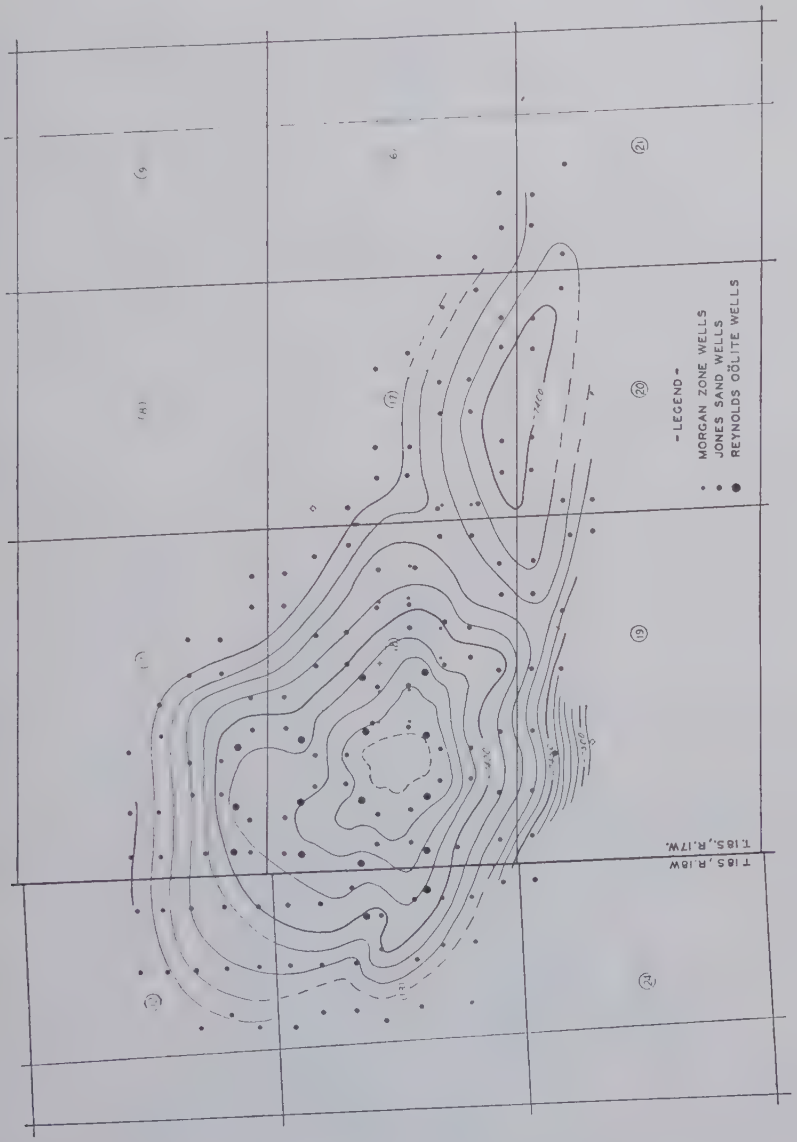
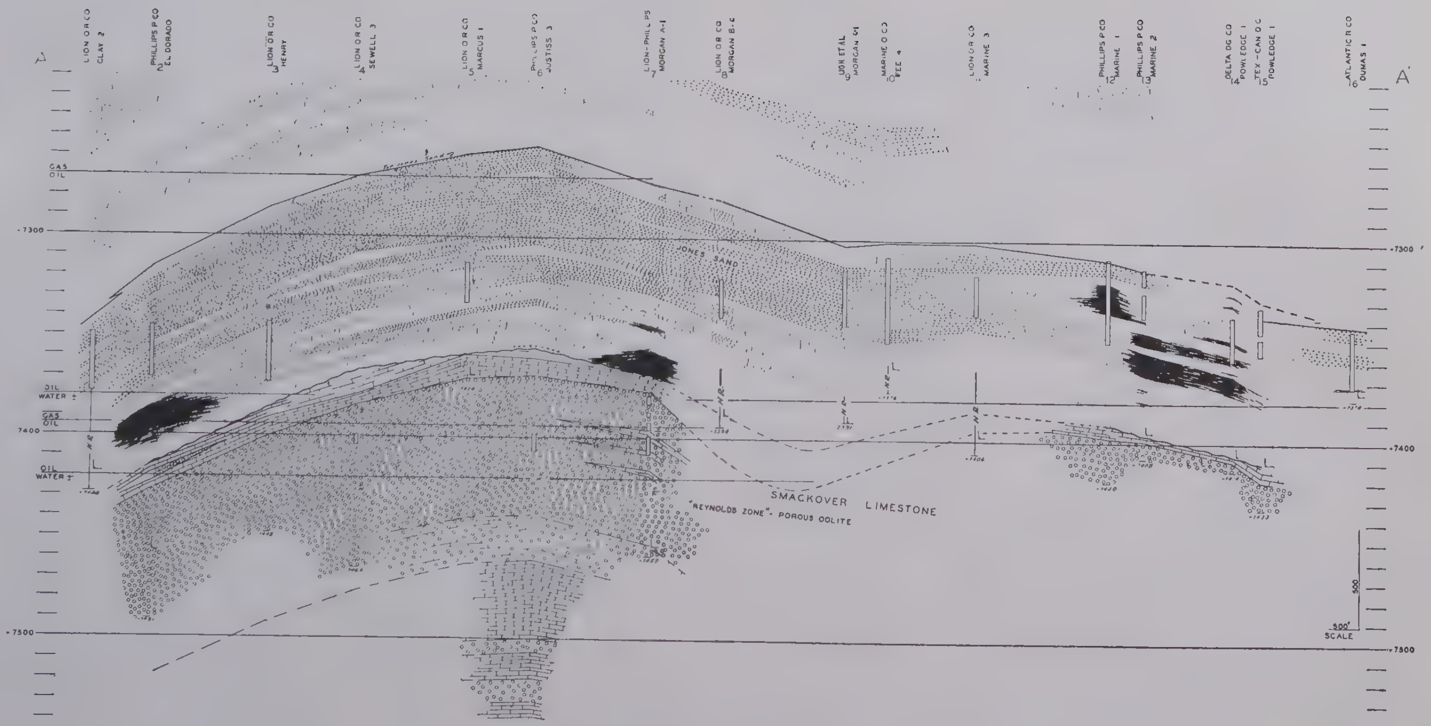


FIG. 3.—STRUCTURAL CONTOURS, TOP REYNOLDS OÖLITE POROSITY, SCHULER FIELD.



WEST - EAST SECTION A - A'

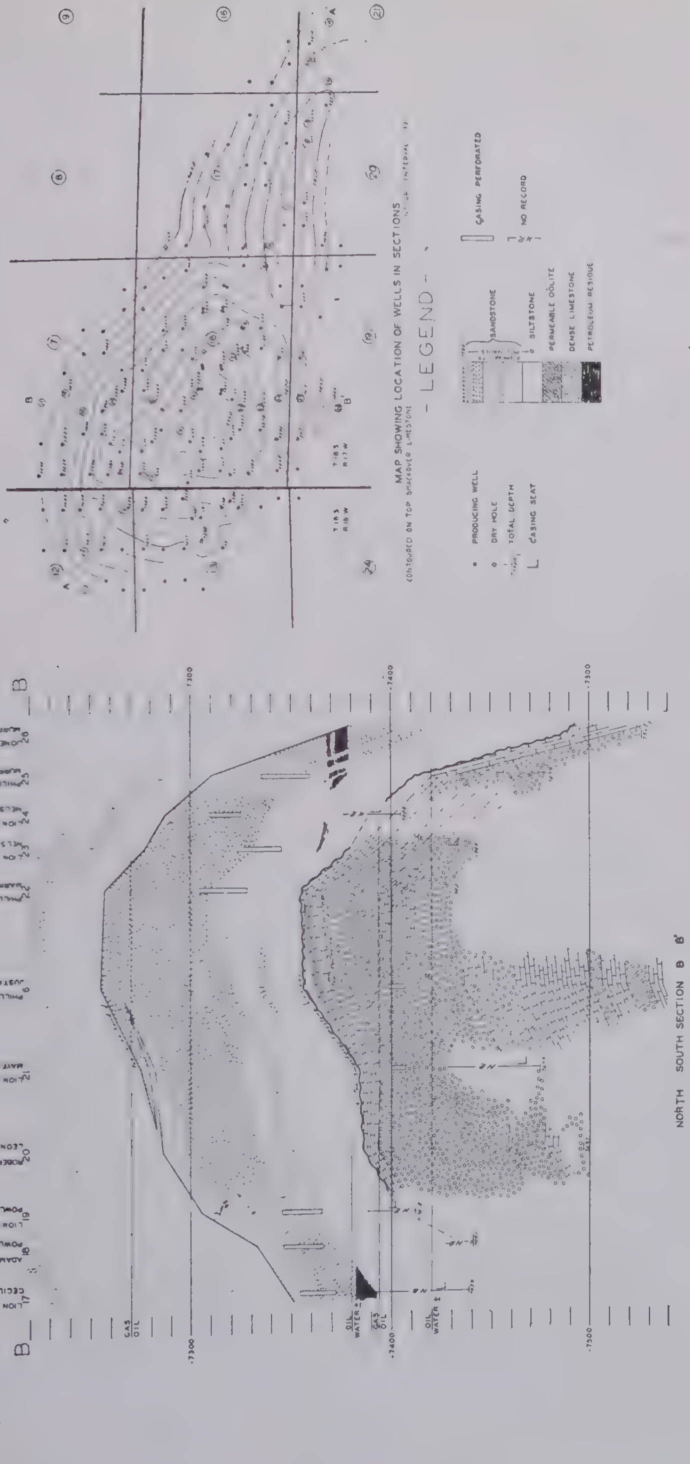


FIG. 4.—CROSS SECTIONS OF LOWER PRODUCING ZONES, SCHULER FIELD.

asphaltic content of the Jones sandstone also suggests the occurrence of multiple accumulation in the past.

Evidence against migration between the two pools rests on the fact that the reservoir liquid in the Jones sand pool is quite different in composition from that in the limestone, and shows no detectable variation across the pool. The Reynolds gas contains about 1500 grains of hydrogen sulphide, while Jones gas contains 10 to 350 grains, the higher content being found on the east side of the pool. Any connection between the reservoirs that may have existed in the past is not now effective enough to influence the behavior of the Jones pool under production.

The oil and gas in the Cotton Valley formation differ from those in either the Jones sand or Reynolds formations. No hydrogen sulphide is present. The oil is of higher gravity and differs in hydrocarbon composition sufficiently to suggest a source different from that of the petroleum in the two lower horizons.

PRODUCTION HISTORY OF COTTON VALLEY FORMATION

Drilling for Cotton Valley production ceased after the initial completion of 14 producing wells and 7 dry holes. Of these 14 original wells, 13 were still producing on Jan. 1, 1943. Their accumulated production was 2,509,000 bbl. The oil produced is in the range of 40° to 43° A.P.I.

Initial reservoir pressures in the lenticular sandstones are normal for their depth. The flowing life of the wells depends upon the volume of free gas as well as upon the volume of water encountered, but in general it is relatively short.

The prospects for increasing ultimate recovery from the Cotton Valley formation were enhanced by an amendment, effective Jan. 7, 1942, enlarging the Jones sand unit to include all of the Cotton Valley formation within the unitized area except the parts held by production from the original 14 wells. As a consequence, the Shuler unit may now use Jones sand wells permanently or temporarily plugged back to produce Cotton Valley oil, and a substantial volume of otherwise unrecoverable oil will be recovered in that manner.

Seven Jones sand wells have been recompleted to Cotton Valley wells in the Jones sand unit since Jan. 7, 1942. Their accumulated production to Jan. 1, 1943, was about 200,000 barrels.

PRODUCTION HISTORY OF THE REYNOLDS OÖLITE

The production history of the Reynolds oölite at Schuler is typical of the Smackover lime production in South Arkansas. Reservoir pressure has been maintained by very active water encroachment. The encroachment into the relatively small reservoir has been quite regular in spite of the large variation in specific permeability in the section.

The initial static reservoir pressure was 3530 lb. per sq. in. gauge at 7300 ft. subsea. The reservoir temperature is 200°F. The reservoir-volume factor was 1.56 under initial conditions. The original solution gas was 930 cu. ft. per barrel of residual oil measured by differential vaporization at 200°F.

The initial gas cap and water encroachment led to long flowing life. Wells continue to flow their allowable with as much as 75 per cent water production. The producing gas-oil ratios have remained low, i.e., in the range 800 to 1500 cu. ft. per barrel. The allowable production has been 150 bbl. per day to 40-acre units over most of the prorated period and is assigned on an "acre-pounds" basis.

Approximately 13 to 15 million barrels of pipe-line oil were initially in place in the Schuler Reynolds oölite. On Jan. 1, 1943, the accumulated production was 4,012,000 bbl. The static reservoir pressure at that time was 3353 lb. per sq. in., gauge at 7300 ft. subsea. Fifteen wells are still producing although the edge wells are now making high percentages of water and are near depletion. The stock-tank oil is 36° to 38° A.P.I. gravity.

CHARACTERISTICS OF JONES SAND FORMATION

Core-analysis Data

In oil-field parlance, the Jones sand sandstone might be classified as a "good" oil sand. The angular sand grains vary in texture from fine to medium size. The weighted average porosity is 20.2 per cent. The weighted average specific permeability is about 400 millidarcys in the range of zero to 4000 millidarcys.

The Jones sand has been studied exhaustively by the coring technique. The highly lenticular character of the Cotton Valley sandstones first developed in the field required very close supervision of the drilling operation and the use of every device to determine stratigraphy and the presence of productive sections. As a consequence, a well organized program of measuring drilling time, examining cuttings, and coring and core analyses was developed. That detailed program was continued in drilling the Jones sand pool.

In all, 165 wells have been drilled into the Jones sand, of which 146 were Jones wells, 3 were dry holes, and 16 were Reynolds oölite wells. All but three of these were drilled through the Jones sand into the limestone below, according to the practice of setting casing into the limestone to provide a good casing seat.

Cores were cut in the Jones sand in 146 wells, 88 per cent of the total drilled into that formation, and the entire section was cored in 136 wells (82 per cent.) The sandstone core-drilled amounted to 9827 ft. and the total recovery was of 8292 ft. (84 per cent). The cores were analyzed and studied in a field or near-by laboratory, with very close cooperation between the geologists and core analysts of the several companies. Subsurface electric logs were run in 162 wells and drilling-time logs were kept on nearly all wells, and, when necessary, the properties of unrecovered cores could be estimated from these records.

The core data have proved to be extremely useful in well completion, production control, reservoir engineering study, and in guiding the gas-injection operation now being carried on. The value of the core-analysis data is greatly enhanced by the completeness of the records, since they cover the entire area of the reservoir Deductions based upon core-analysis data are often criticized on the premise that rock recovered from a well bore cannot represent the average character of the surrounding reservoir. Such a contention fails when the reservoir is sampled at as many points as it was in developing the Jones sand.

Fig. 5 was prepared by Weeks and Alexander[1] to show a typical section in both the Jones and Reynolds formations. The drilling-time logs correlated unusually well from location to location and proved to be extremely useful in locating tops of porosity and coring points. The irregularities in the electric-log curves are very rough qualitative indices of the presence of strata of low permeability but only the actual core-analysis data provide useful information on the permeability, porosity, and saturation.

Figs. 6, 7 and 8 are additional coregraphs intended to show other representative sections of the Jones sand. The specific permeability profile is of particular interest. A wide variation exists in specific permeability. This is true for the thicker sandstone as well as for the thinner section shown in Fig. 8, representative of the silt-bearing and asphalt-bearing section on the east. The permeable strata are not correlative between locations or across the pool. One might conclude that the local inhomogeneities are so distributed as to yield over all a more or less homogeneous

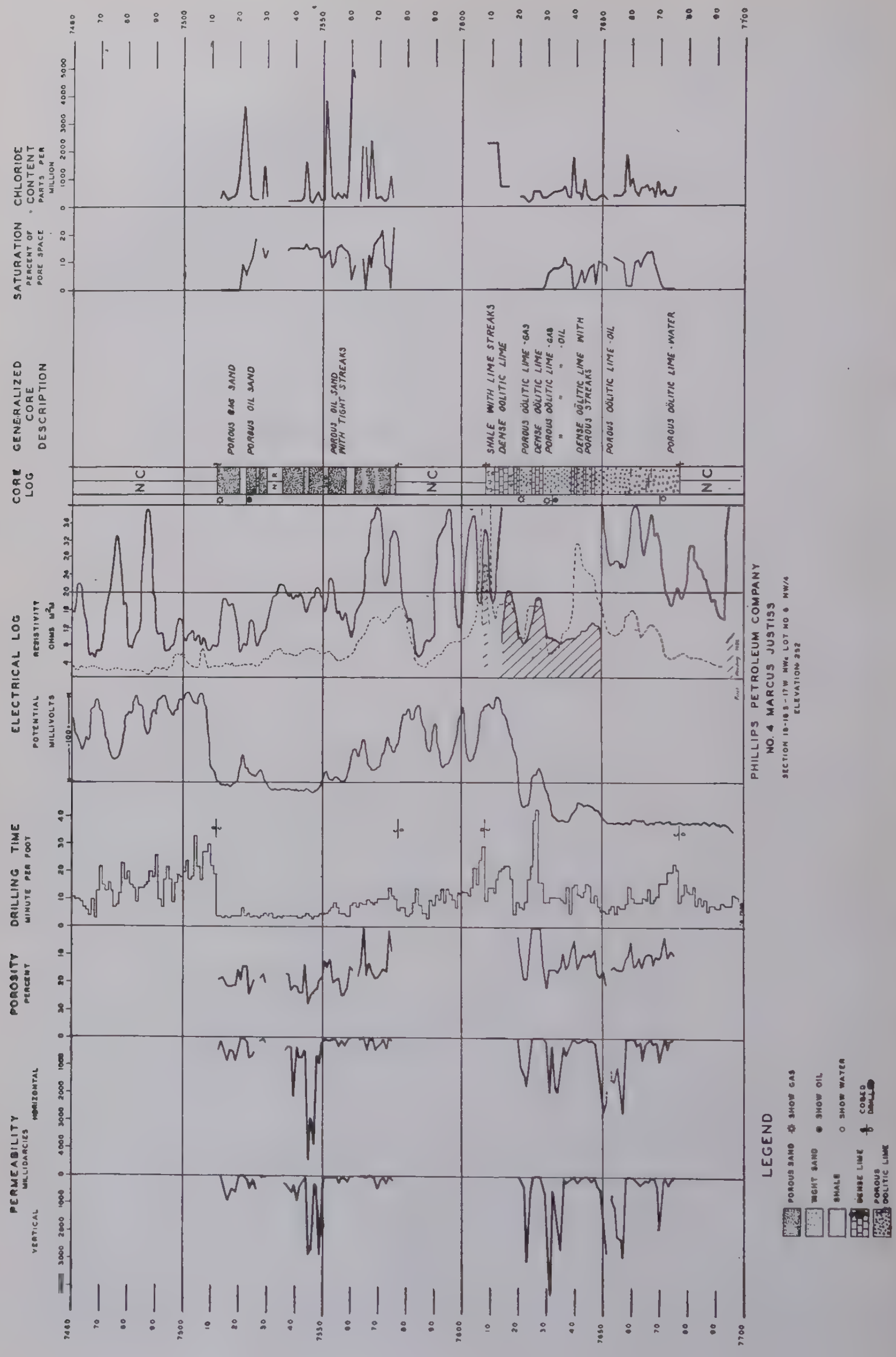


FIG. 5.—TYPICAL RECORD THROUGH JONES SAND AND SMACKOVER LIME.

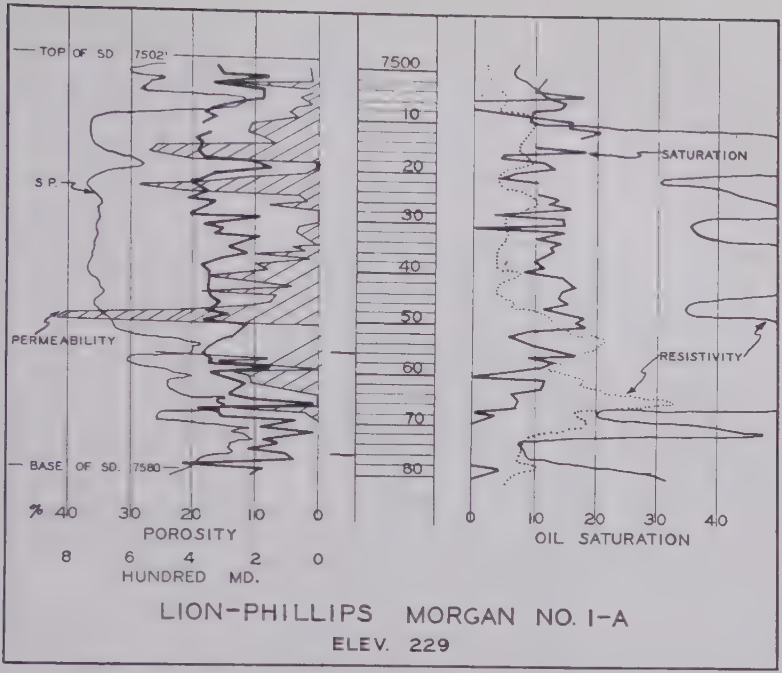


FIG. 6.—COREGRAPH, JONES SAND.

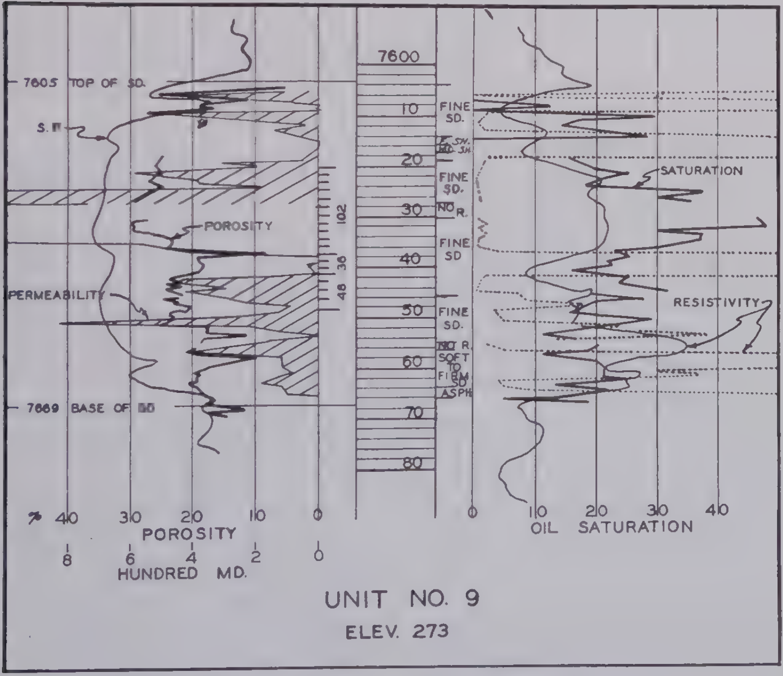


FIG. 7.—COREGRAPH, JONES SAND.

sand as far as response to a gas-drive production process is concerned. The degree of shading in Fig. 4 is intended to give a qualitative index of the distribution of permeable sand based on the results of core analyses along one cross section. The darker shading corresponds to higher specific permeability except for the solid black, which represents asphaltic residues.

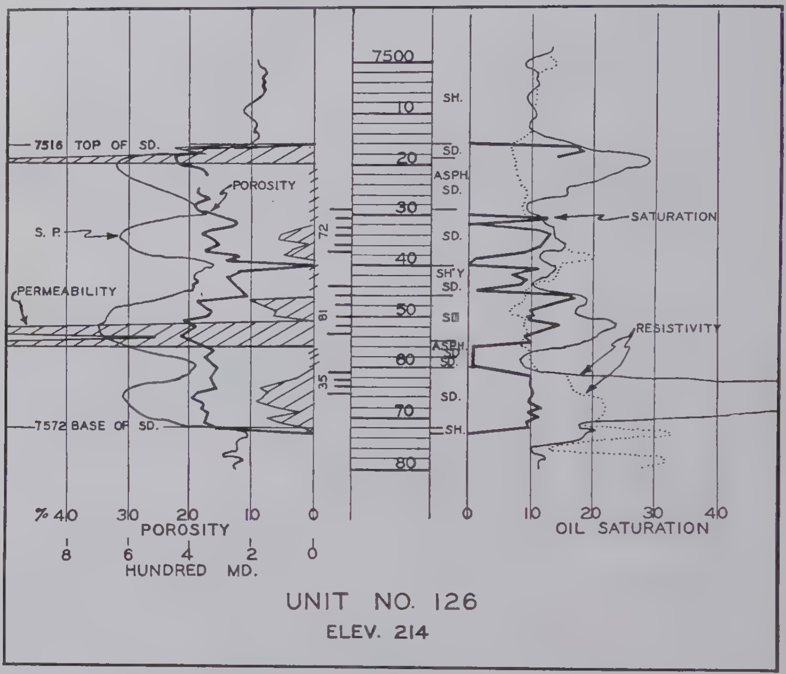


Fig. 8.—Coregraph, Jones sand.

The extensive core data permit an exceptionally accurate estimate of the thickness of permeable saturated sand in the wells, and from this an accurate estimate of the oil in place in the pool and its distribution between areas of the pool that provides a basis for understanding the behavior of the Jones reservoir pressure.

Bottom-hole Sample Data

A bottom-hole sample of reservoir liquid from the Jones sand was taken on Dec. 11, 1937, from Unit Well No. 48. The hydrocarbon analysis of that sample with related data are summarized in Table 1. Solubility-shrinkage curves were determined by differential vaporization at 198°F., the reservoir temperature, and are given by the solid curves of Fig. 9. These results are expressed on a residual oil basis.

Table 1.—*Analysis of Reservoir Liquid, Jones Sand Pool, Schuler, Arkansas*

Component	Mol Per Cent
Carbon dioxide	0.80
Nitrogen	1.00
Methane	42.85
Ethane	6.60
Propane	4.10
Butanes	3.64
Pentanes	3.10
Hexanes	3.83
Heptanes-plus	34.08

Molecular weight, heptanes-plus = 243
Specific gravity, heptanes-plus = 0.8759
Formation temperature, deg. F. = 198
Observed flowing pressure, lb. per sq. in. = 3370
Observed saturation pressure, lb. per sq. in. = 3230

Samples of reservoir liquid were taken by two independent groups in November and December 1941, respectively, from Unit Well No. 42. These were analyzed, with almost identical results, to yield the solubility-shrinkage data shown by the dotted curves in Fig. 9. The observed difference between the two samples is about 10 per cent in the higher pressure range. The difference might be due to an error in the analysis of the original sample. It could hardly have arisen from the effects produced by the dry gas injected before the second sample was taken. On the other hand, the difference might indicate that change in composition of reservoir liquid in response to decline in reservoir pressure does not follow the differential vaporization process as carried out in the laboratory determination. This is quite likely, but additional data must be obtained to permit a conclusion.

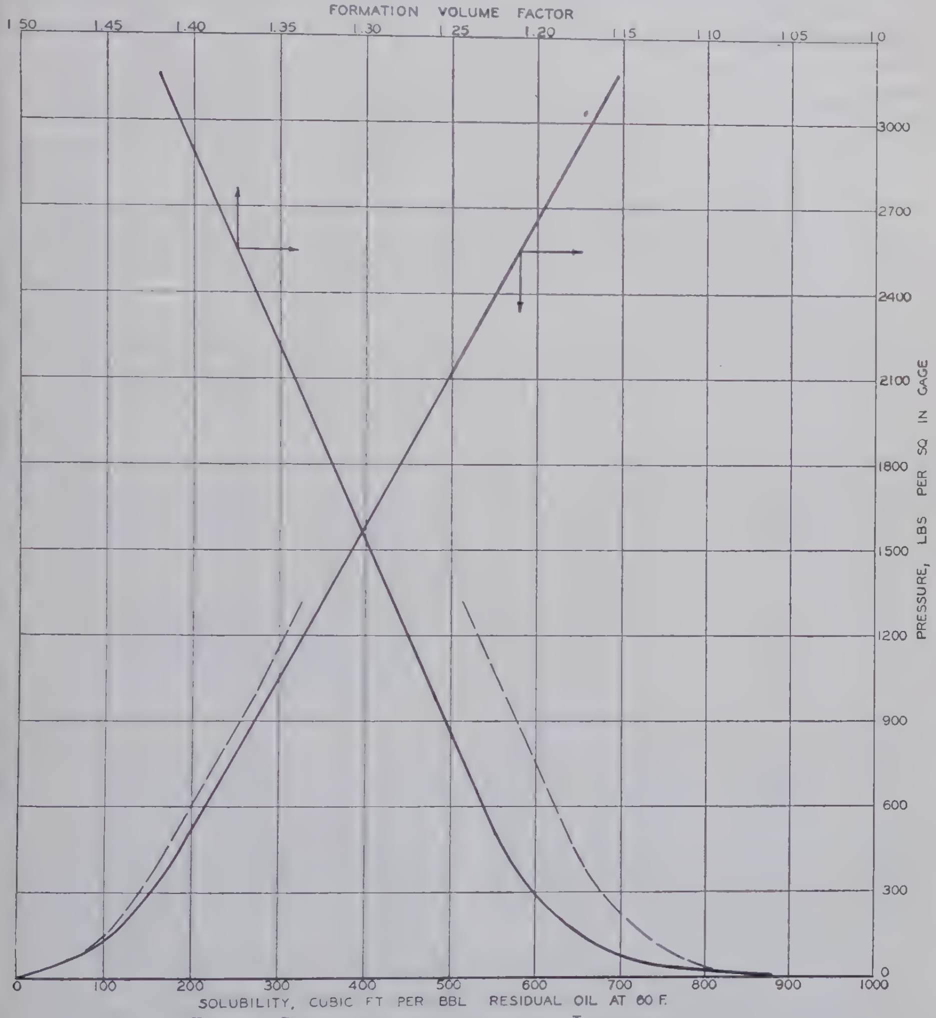


FIG. 9.—SOLUBILITY-SHRINKAGE DATA, JONES SAND POOL.

The stock-tank liquid produced from the Jones sand is in the range 32° to 34° A.P.I.

PRORATION HISTORY OF JONES SAND

The Jones sand pool was produced without formal regulation from discovery in September 1937 to Jan. 1, 1938. The maximum number of wells was eight, and they were produced at an average rate of 1000 to 1300 bbl. per day.

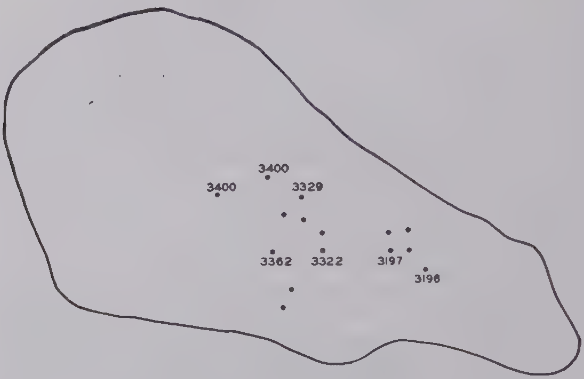


Fig. 10.—Reservoir-pressure survey, Feb. 22, 1938.

On Jan. 1, 1938, operators agreed to voluntary allocation of the market demand. The formula adopted employed "acres plus reservoir pressure," with distribution of allowable placed under supervision of the then recently created Arkansas Oil and Gas Commission. In that month, 10 wells were assigned a 20-acre unit allowable of 400 bbl. per day.

On Apr. 1, 1939, the Arkansas Oil and Gas Commission, empowered under Legislative Act No. 105 effective Jan. 1, 1939, fixed the allocation formula on an "acre-pounds" basis. In that month, 126 wells were producing the 15,000 bbl. per day allowable to the pool and the allowable to 20-acre units was in the range of 95 to 128 bbl. per day.

The pool allowable was reduced to 13,500 bbl. per day in October 1940.

The allocation to drilling units was subject to a limiting permissible gas-oil ratio of 2500 cu. ft. per barrel up to this time.

When the Jones sand pool was unitized on Feb. 15, 1941, except for two tracts having six of the 146 Jones wells, the method of allocating production was changed. The Arkansas Oil and Gas Commission, by an order effective in April 1941, fixed the basic distribution of Jones sand allowable by assigning 95.7564 per cent to the unitized area and 4.2436 per cent to the two tracts outside the Unit. After gas-injection operations were initiated in the Unit area on July 1, 1941, the basic allowable distribution was modified to include a "net volumetric withdrawal" factor. The basic allocation is thereby adjusted each month to account properly for the "net" gas produced on the respective allocation units. This formula is currently in use.

The allowable for the Jones sand pool was decreased in April 1942, from 13,500 bbl. to the current allowable of 12,000 bbl. per day.

Reservoir-pressure History of Jones Sand Pool

The reservoir-pressure history of the Jones sand pool is one of the most interesting features of the reservoir's performance. It is an interesting and instructive index of the reaction of a pool to proration, production and conservation practices. Reservoir-pressure surveys have been made every month with few exceptions from discovery to June 1942, when bimonthly surveys were begun. Fifteen to 20 key wells, with wells in the immediate area also closed in for a period of at least 24 hr., were used in each survey.

The initial static reservoir pressure was 3520 lb. per sq. in. gauge at 7300 ft. subsea.

As early as February 1938, the reservoir-pressure survey, as shown in Fig. 10, revealed a well-defined reservoir-pressure gradient. The lower pressure in the eastern area about the discovery well, with increasing pressure toward the west, continued thereafter to be an important feature of the pool's behavior. By the time the one hundred and forty-sixth producing well was completed in July 1940, the reservoir pressure map appeared as shown by Fig. 11. By the time the Jones sand unit was formed on Feb. 15, 1943, the pressures were as shown by Fig. 12.

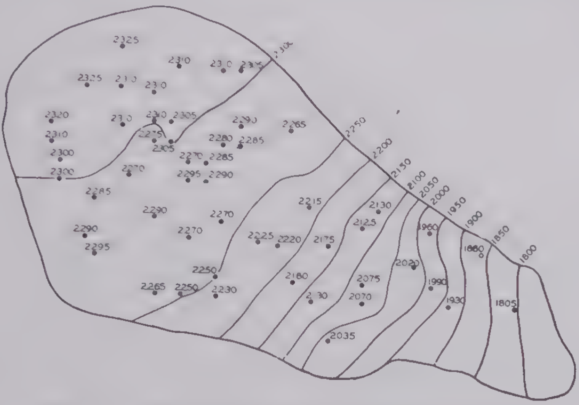


FIG. 11.—RESERVOIR-PRESSURE SURVEY, JULY 1940.

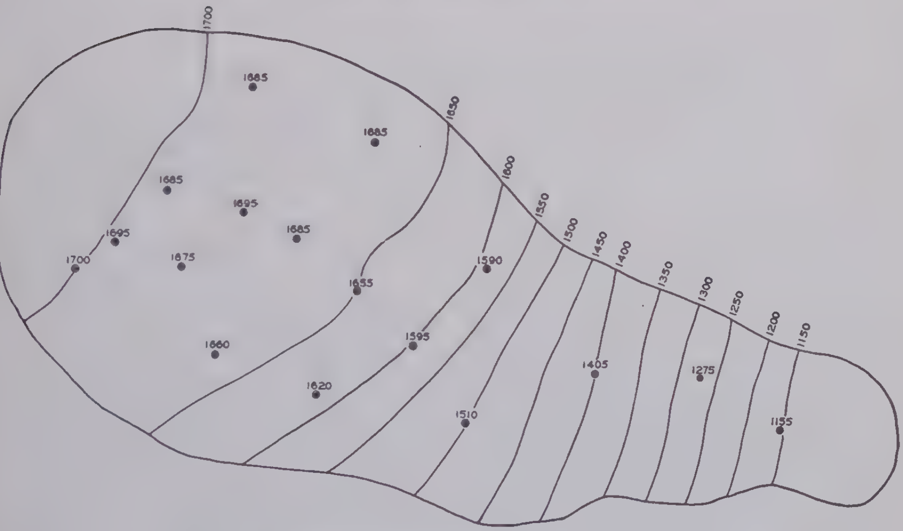


FIG. 12.—RESERVOIR-PRESSURE SURVEY, FEB. 15, 1941.

These examples are representative of the reservoir-pressure history in the period from 1937 to 1941 before unitization. The maximum differential between east and west existed early in 1939 and was about 800 lb. per sq. in. Several factors contributed to the development and maintenance of the reservoir-pressure differential. In general, it may be said that accumulated withdrawals from respective areas of the

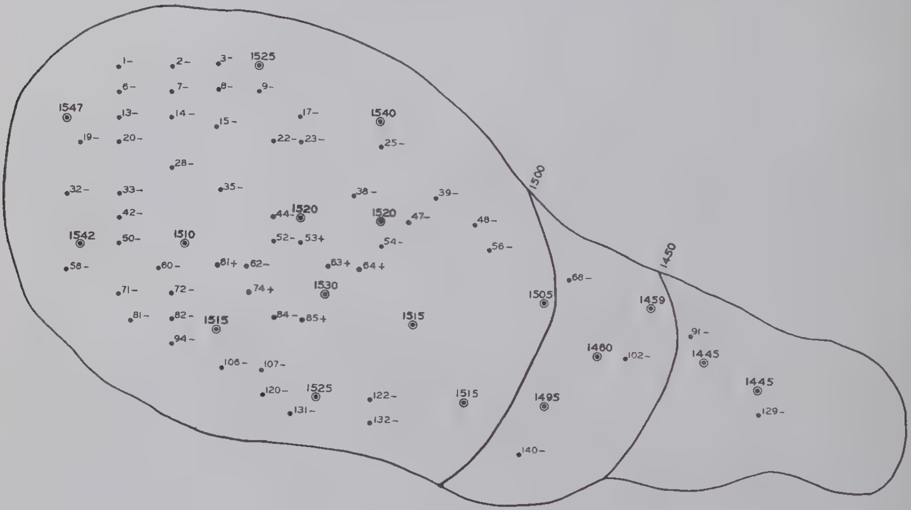


FIG. 13.—RESERVOIR-PRESSURE SURVEY, JULY 25, 1941.
A plus sign indicates an injection well; a minus sign, a producing well.

pool were not proportional to recoverable oil initially in place, while, at the same time, the rate of such withdrawals exceeded the rate of areal migration of fluids through the sandstone. The pool was discovered in the relatively thin sandstone section in the east, and early development centered there. In addition, the allocation of production was based upon factors that did not fully weigh, relatively, the quantities of recoverable oil and gas in place under respective drilling units. A third factor was the proportionately greater volumetric withdrawal per barrel of oil produced from the east area. It is a fact, and one rather expected from laboratory studies of polyphase flow, that producing gas-oil ratios of Jones wells were correlative with the inverse of the average specific permeability of the sandstone exposed. Wells in the eastern area generally showed higher ratios, which increased rapidly with accumulated production. The resultant higher volumetric withdrawals contributed in large measure to the reservoir-pressure gradient.

One feature of the east-west gradient was its uniformity. In late 1940, the gradient was uniform at 4 lb. per sq. in. per 100 lin. ft. over three fourths the distance from east to west. This pressure condition suggested flow through a linear channel more or less the general shape of the pool in the direction of the gradient.

Up to Feb. 15, 1941, the average static pressure of the Jones pool declined in a fairly regular manner with accumulated production. The trend was toward an accelerated pressure decline due to rapidly increasing average gas-oil ratios in the pool, caused by the increasingly high ratios of wells in the low-pressure east area. The formation of the Jones sand unit enabled the 12 member operators to take steps to arrest the decline in reservoir pressure. Wells with high producing gas-oil ratios were shut in, and the unit allowable was produced from the most efficient wells in the unit. This step in itself was highly effective in reducing the rate of pressure decline. The next effective step was to institute a gas-injection pressure-maintenance program designed to return to the reservoir 90 per cent of the gas produced.

Gas injection was begun in July 1941. The reservoir-pressure map for that month is shown in Fig. 13. Significant changes over the short period of gas conservation initiated in February 1941 were already evident. The pressure difference from east to west was reduced from 545 to 102 lb. per sq. in. in that time. The locations of the injection wells and the wells used to obtain production in July 1941 are shown in Fig. 13.

The quick response of the reservoir pressure to both the gas-injection operation and the production of only the lower ratio wells is evident from the reservoir-pressure survey of December 1941, shown in Fig. 14. The reservoir-pressure survey of November 1942 (Fig. 15) can be interpreted generally from the discussion to follow.

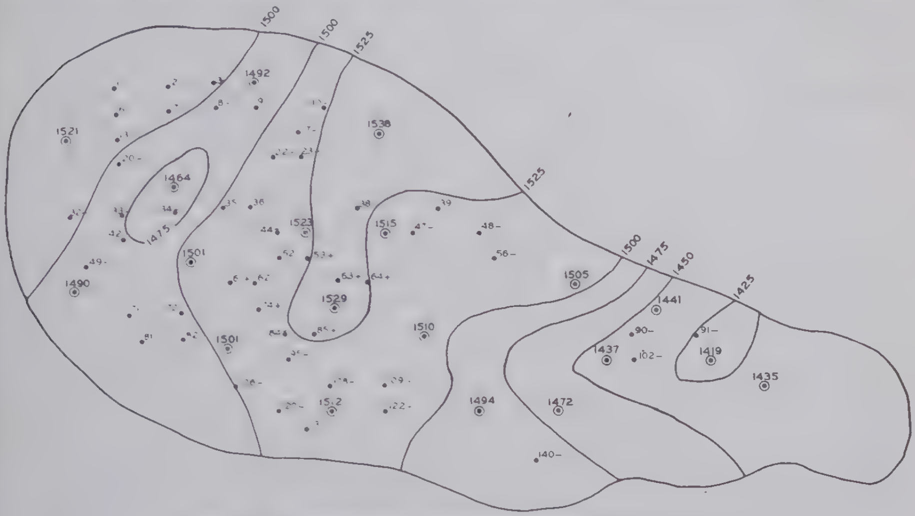


FIG. 14.—RESERVOIR-PRESSURE SURVEY, DEC. 22, 1941.

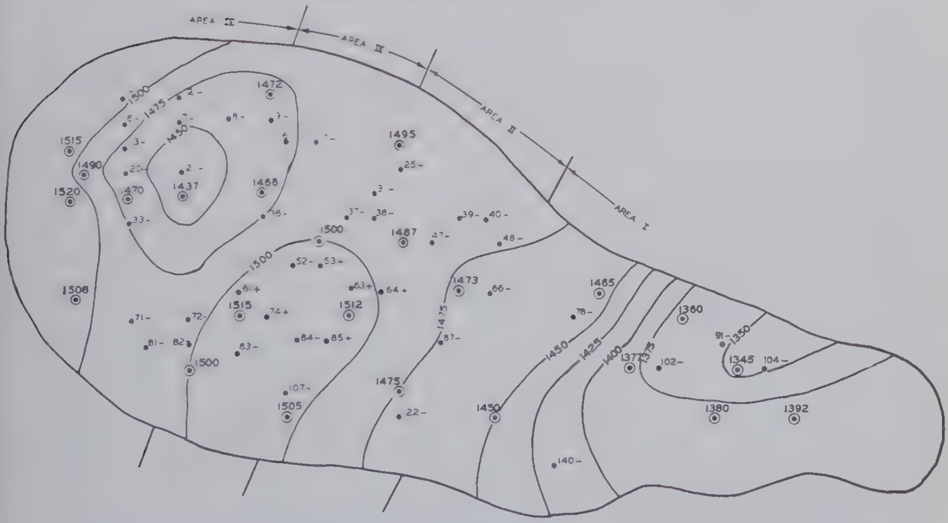


FIG. 15.—RESERVOIR-PRESSURE SURVEY, NOV. 28, 1942.

PRODUCTION STATISTICS, JONES SAND

The accumulated production and reservoir-pressure statistics for the Jones sand pool are summarized in Table 2. These data are represented graphically by the solid curves of Fig. 16, which illustrate points in the preceding discussion and relate to the dotted curves of the figure in a manner to be discussed.

allowable could be taken from low-ratio wells. The several large reductions in producing gas-oil ratio accomplished after gas injection was begun resulted from installing gas-lift equipment in four wells in the west area of the pool.

TABLE 2.—*Production Statistics, Jones Sand Pool, Schuler Field, Arkansas*

End of Month	Average Reservoir Pressure,[a]		Average Gas-oil Ratio, Cu. Ft. per Bbl.			Cumulated Salt Water, Bbl.[b]	Cumulated Oil, Million Bbl.	*n*
	Areal	Volumetric	Producing for Period	Net for Period	Accumulated Net Produced			
1937								
Sept. 17	3,548	3,548	750	Same	750	0	0	
1938								
January	3,459	3,448	850	Same	820		0.476	92.83
April	3,283	3,303	920		880		1.743	132.49
July	3,148	3,153	990		917		2.818	125.41
October	2,898	2,938	1,020		966		4.653	123.52
1939								
January	2,790	2,813	1,000		974		6.030	125.54
April	2,628	2,678	1,180		999		7.360	122.96
July	2,468	2,533	1,420		1,054		8.751	120.72
October	2,408	2,453	1,510		1,108		9.873	125.41
1940								
January	2,265	2,318	1,660		1,170		11.259	124.05
April	2,109	2,153	1,920		1,239		12.619	118.52
July	1,910	1,978	2,220		1,331		13.998	114.14
October	1,753	1,818	2,480		1,422		15.321	111.63
1941								
January	1,598	1,658	2,710		1,509		16.552	108.62
February	1,593	1,625	2,800–1,463		1,523		16.929	108.65
March	1,597	1,635	1,414		1,520		17.348	112.16
April	1,578	1,603	1,458		1,519		17.757	111.50
May	1,568	1,588	1,566	Same	1,520		18.177	112.69
June	1,544	1,565	1,712	Same	1,524	149	18.583	113.10
July	1,528	1,542	1,834	955	1,512	201	19.006	112.65
August	1,510	1,533	1,733	320	1,486	201	19.426	113.04
September	1,518	1,530	1,656	236	1,461	266	19.830	113.15
October	1,523	1,534	1,687	238	1,435	386	20.249	114.28
November	1,526	1,534	1,740	183	1,411	386	20.652	114.99
December	1,520	1,528	1,736	200	1,387	386	21.068	115.10
1942								
January	1,517	1,524	1,769	278	1,366	386	21.474	115.46
February	1,515	1,521	1,965	314	1,348	386	21.850	115.97
March	1,515	1,521	2,052	249	1,328	386	22.261	116.76
April	1,513	1,521	1,600	231	1,310	706	22.619	117.36
May	1,504	1,521	1,394	126	1,291	1,032	22.991	117.91
June			1,657	202	1,274	1,690	23.351	
July	1,517	1,510	1,780	141	1,256	3,877	23.722	117.90
August			1,972	135	1,239	9,554	24.094	
September	1,498	1,508	1,970	112	1,223	17,011	24.454	118.83
October			2,075	145	1,206	34,725	24.824	
November	1,488	1,500	2,252	119	1,196	51,799	25.187	119.70
December			2,382	59	1,174	64,920	25.550	
							Average	116.5

[a] Reservoir pressure, pounds per square inch absolute at 7340 ft. subsea, the average depth of oil-saturated section.

[b] Does not include water produced outside unitized area.

The substantial reduction in producing gas-oil ratio, and resultant conservation of reservoir pressure even before gas injection was begun, was immediately accomplished by producing only the most efficient wells in the unit. The reduction in pool allowable from 13,500 to 12,000 bbl. per day was also a factor, in that a greater portion of the

One real measure of the success of unit operation is apparent from Fig. 16. By Jan. 1, 1943, the accumulated oil production was about 25 million barrels, or approximately 21 per cent of the initial oil in place.

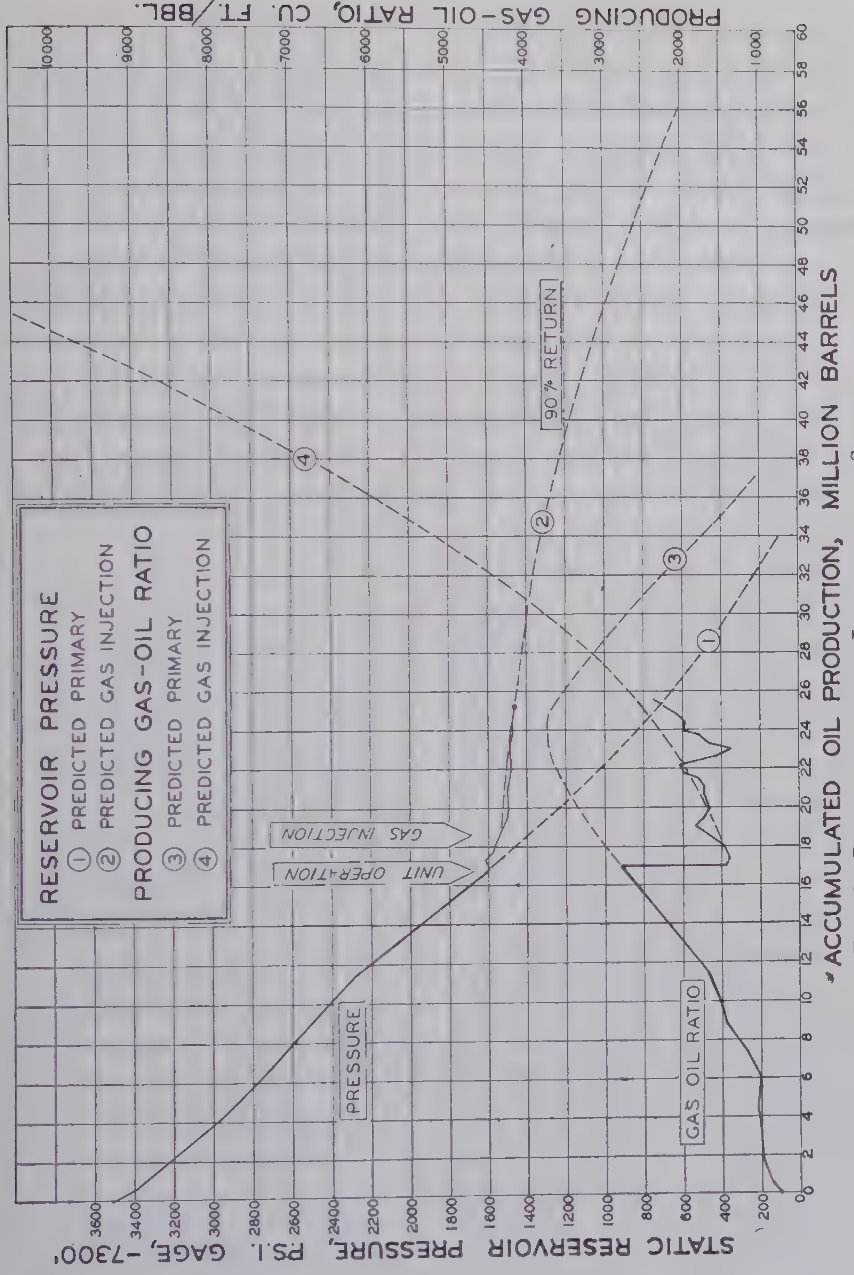


FIG. 16.—PRODUCTION HISTORY, JONES SAND POOL, SCHULER FIELD.

And yet, over-all, the producing gas-oil ratio for the pool was only about 2400 cu. ft. per barrel, or 85 per cent of the producing ratio of Feb. 15, 1941, when but 16.5 million barrels had been recovered. The recovery of 8.5 million barrels under the unit secondary program was accomplished with a pressure decline of only 125 lb. per sq. in., whereas a decline of about 800 lb. per sq. in. would have been expected under continuation of primary operations.

Unitized Operation of Jones Sand Pool

The Jones sand unit was formed Feb. 17, 1941, and provided for the respective consolidation of the royalty and working interests in all but two leases having six of the 146 wells in the Jones pool. The Lion Oil Refining Co., El Dorado, Ark., was elected Unit operator subject to a Unit Operating Committee representing the 12 owners of working interest. Many improvements in operating practices and steps to increase the efficiency of the oil-recovery operation were possible under unit management. The pool average producing gas-oil ratio was greatly decreased, a gas-injection pressure-maintenance program was begun, natural flow of producing wells was maintained, physical equipment was conserved and salvaged, and operating economies were effected.

Immediately upon formation of the Jones unit, the average producing gas-oil ratio of the pool was reduced from 2800 to less than 1500 cu. ft. per barrel, by the simple expedient of producing only the most efficient wells. Each month the unit allowable has been produced from less than 50 of the 140 unit wells. This continues to be one of the most effective measures in conserving reservoir gas and reservoir withdrawals. The unit wells used for production lie, for the most part, in the western half of the pool, where oil potentials are still high and the producing gas-oil ratios of many wells are as low as 500 to 1000 cu. ft. per barrel. The greater thickness and average specific permeability of the sandstone in the western area account in part for the continued high productivity of these wells, but a more important factor is the relatively greater remaining recoverable oil saturation.

Guide lines have been drawn on Figs. 15 and 17 perpendicular to the principal axis of the pool, to divide the pool into four areas of equal saturated productive sand volume. The history of accumulated oil production of these four areas is summarized in Table 3. The disproportionate withdrawals from the four areas were the result of the manner in which the pool was developed by drilling, and also the distribution of allowable under the allocation formulas employed. The disproportionate withdrawals also created the reservoir-pressure gradient. Even though the practice of producing only the most efficient wells has concentrated withdrawals in the higher-pressure area IV, the accumulated withdrawals as between the areas of equal productive sand volume are not yet in balance. One may note that the relatively small current rate of production from Area I is still great enough to maintain the low reservoir pressure in that area. This reflects the influence of high producing gas-oil ratios, and consequently larger volumetric withdrawal per barrel produced.

TABLE 3.—*Accumulated Oil Production, Areas of Equal Saturated Sand Volume, Jones Sand Pool*

Period	Oil Production, Thousands of Barrels			
	Area I	Area II	Area III	Area IV
9-17-37 to 2-14-41	5,980	4,833	3,228	2,711
2-14-41 to 1-1-42	353	1,045	1,108	1,826
1-1-42 to 10-1-42	402	787	859	1,334
9-17-37 to 10-1-42	6,734	6,666	5,196	5,871
Surface area, acres	1,460	836	706	998

The Jones sand pool was on the verge of entering the artificial-lift stage at the time the unit was formed. In fact, the prospects of having to pump the 7500-ft. reservoir was one of the important elements leading to the unitization. Maintenance of reservoir pressure by gas conservation and by gas injection has maintained the flowing life of the wells and the flowing oil potential. Gas lift has been installed on only four unit wells to date. In this way, four high-potential wells in area IV that ceased to flow because of low gas-oil ratio with too low reservoir pressure have been produced and the average gas-oil ratio of the pool has decreased. Gas lift has been installed also to produce the wells making water on the edge of the pool.

If the Jones unit had been formed before the pool's reservoir pressure had declined to about 1600 lb. per sq. in., which was near the critical pressure of flow under the gas-oil ratio existing in the western area, particularly, still greater economies could have been accomplished. The opinion has often been expressed that the earlier a gas-injection program is started, the more beneficial that operation will be, especially if the reservoir is typically gas-drive or depletion type. Experience with the Jones pool bears out that opinion, which, in itself, is founded on sound engineering conclusions.

Packers set on tubing near the top of the casing perforations have been used generally to maintain flow of low-ratio wells, with good success.

The gas-injection program may be classified as a "gas-cap injection operation." To the present time, six of the structurally high wells have served as injection wells. No particular effort is being made to return gas to selected strata. Two of the wells were perforated with five to six shots per foot through most of the saturated section. The others were used with original production perforations in only part of the saturated zone. The injection wellhead pressure in December 1942 was 1330 lb. per sq. in. gauge, the daily volume injected being nearly 26 million cubic feet per day.

The compressor station has 4200 hp. installed. Gas is gathered generally at approximately 275 lb. per sq. in. from the east area; at about 50 lb. per sq. in. from the west area, and at slightly more than atmospheric pressure from the consolidated tank batteries in the unit. The gas is processed in an absorption gasoline plant at 300 lb. per sq. in. and is delivered to the field injection lines at 1450 lb. per sq. in. (December 1942.)

All gas produced from Cotton Valley wells in the field is processed and made available for injection into the Jones sand. The 1500-grain sulphide-bearing gas being produced from the Reynolds reservoir will be processed for its gasoline content, but will not be injected into the Jones pool because of its high content of hydrogen sulphide.

The injected gas has shown a surprising degree of segregation in the reservoir. There is no evidence of any tendency toward differential movement to flood out any area of the pool commonly referred to as "channeling." The increases in producing gas-oil ratio due to injected gas are normal and many wells in the immediate area of injection wells continue to be good oil-producing wells. (See Fig. 15.)

In March 1941, the injection wells became plugged with an oily accumulation of iron scale. The cause of this scale was traced to the 50-grain hydrogen sulphide content of the injected gas reacting in the presence of a very small amount of oxygen in the air entering the system through the stock-tank vapor-gathering system. After steps were taken to eliminate this source of oxygen, and the capacity of the discharge scrubber at the plant was increased, no further difficulties were encountered. The injection wells were restored to their original capacity by washing with gasoline, and later, by washing with a small volume of acid.

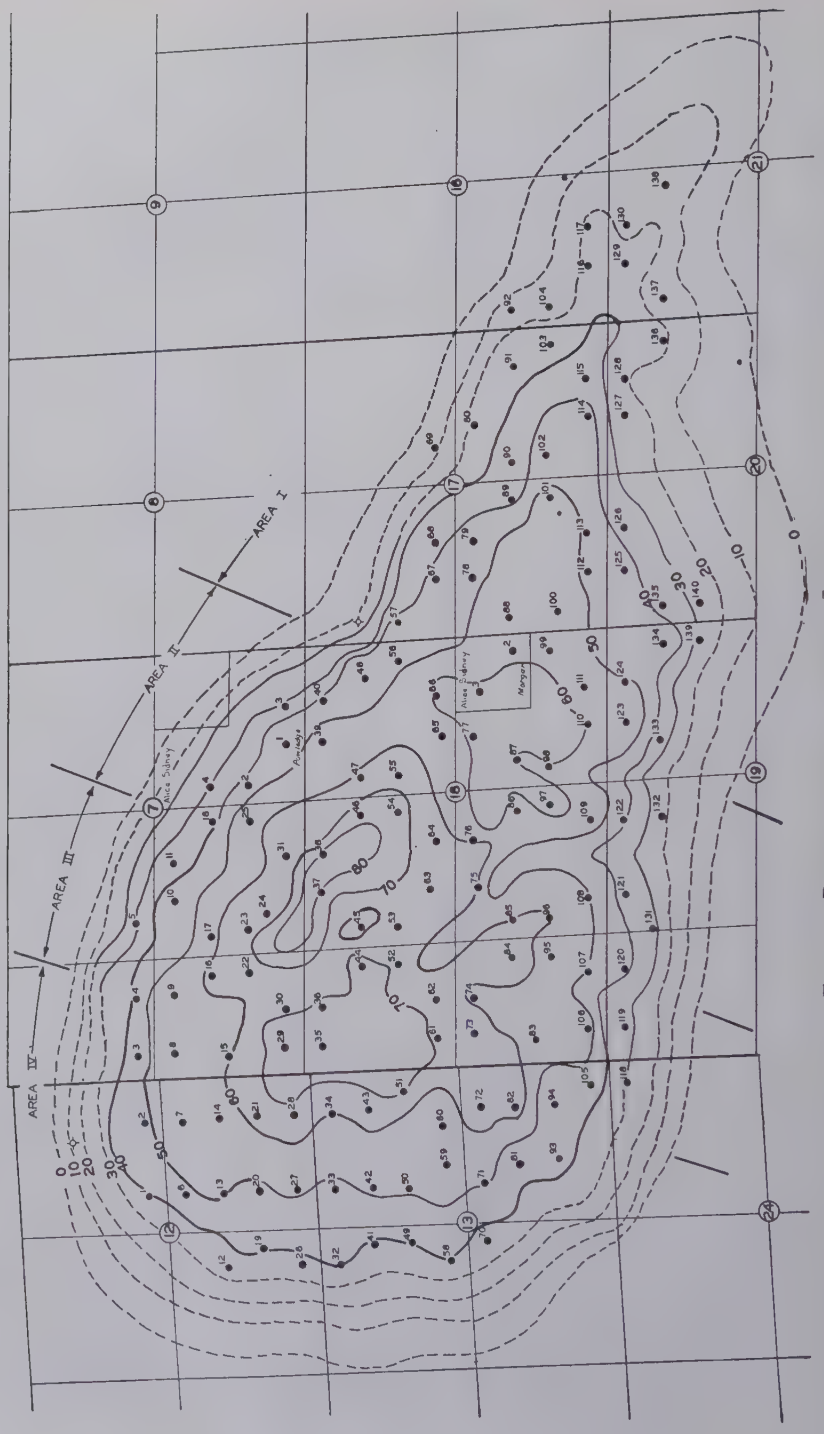


FIG. 17.—PRODUCTIVE SAND THICKNESS, JONES SAND POOL.

ESTIMATES OF OIL INITIALLY IN PLACE

Sand-volume Method.—The Jones sand core analysis and drilling data were complete enough to provide unusually reliable estimates of the oil-saturated "productive" thickness of Jones sand sandstone in wells drilled. Such an estimate was made by deducting all formation thicknesses having a specific permeability of less than 10 millidarcys to produce the isopachous map shown in Fig. 17, referred to as the map of "productive" sand thickness. The productive sand volume is very nearly 150,000 acre-feet.

On the basis of 20.2 per cent porosity, 1.45 initial formation-volume-factor and a connate water content of 25 per cent, this sand volume represents about 122 million barrels of residual oil initially in place. If 35 per cent connate water were assumed, the result would be 106 million barrels.

Material-balance Method.—One of the features of the Jones sand pool reservoir performance is the manner in which it adheres to the "material-balance principle" relating reservoir-pressure decline and accumulated-fluid production. The Jones sand data permit a number of calculations that serve to test the validity of that general principle in this one specific instance.

The material-balance equation applied to the Jones sand can be put into a convenient form as shown in the Appendix. When the static reservoir pressure and accumulated production statistics given in Table 2 are substituted in the equation, using discovery as the initial date for successively longer time-period calculations, and with the assumption that no significant water encroachment into the oil-producing section has occurred, the calculated values for oil initially in place are those given in the ninth column of the table. The average of the 32 calculations for representative time periods from discovery is 116.5 million barrels.

The average result obtained is in excellent agreement with the estimate by the sand-volume method, which could be made identical if the percentage of connate water were set at 28.5.

In applying the material-balance principle to estimate oil in place, the first step usually is to assume no water encroachment. If, on that assumption, consistent values for initial oil in place are obtained for successive time periods, the absence of water drive is proved. On the other hand, if consistent values for initial oil in place are not obtained in that manner, but the calculated result increases continuously in each successive time period, water encroachment is indicated. The theory of the principle then requires the use of appropriate terms to correct for the effect of encroached water on the estimated value of oil in place, and a solution for both oil in place and rate of water encroachment must be obtained.[3,4]

The calculated values for oil initially in place reported in Table 2 are not entirely consistent, but they are consistent enough, after consideration of unavoidable errors in the essential data, to lead to the conclusion that the result obtained for oil in place is reasonably accurate, and that water encroachment into the pool is negligible.

If the solubility-shrinkage curves obtained on the bottom-hole samples in December 1941 are used, the oil-in-place calculations indicate about 125 million barrels in place with substantially the same consistency between time periods.

THE QUESTION OF WATER DRIVE

The material-balance calculations establish the Jones sand pool as a gas-drive or depletion-type reservoir entirely. This opinion is contrary to conclusions reached in a recent paper.[5] The probable absence of significant water encroachment is indicated also by indirect evidence. The geologic structure and the presence of silt and asphaltic residues on the flank of the oil-saturated section and thinning of the section suggest a closed reservoir limiting the volume of water associated with the oil. The reservoir-pressure contours do not suggest flank encroachment of water. Furthermore, water production from the unitized area has been relatively insignificant, as well as confined to outside wells, in spite of the reservoir-pressure decline of about 2000 lb. per sq. in. and 21 per cent recovery of the oil initially in place.

At the present time, all of the outside wells about the entire flank of the Jones pool produce water in amounts up to 60 per cent of total liquid produced. The water production from the Jones unit has increased in recent months, mainly because these edge wells in the west area have high oil potentials with low producing ratios and are being kept on high rates of production. There is no evidence that water production in the edge wells is increasing at a rate even suggestive of a significant rate of encroachment.

Those who are particularly interested in the test of the material-balance calculation will note a trend in the calculated values of oil in place in Table 2, ninth column, beginning with unit operation in February 1941. The increase is not as large as would be expected if water encroachment existed. The significance of that trend cannot be explained with present information. It may be due to one of a number of unavoidable sources of error, particularly in the value of the average static reservoir pressure determined from observations in key wells, or possibly may be caused by failure of the differential solubility-shrinkage curves to represent the reservoir process, especially under gas-injection operations.

CONSERVATION UNDER UNIT OPERATION

Increased Ultimate Recovery

The importance and significance of the Jones sand unit will rest in the substantial increase in ultimate oil recovery as a result of the gas-injection pressure-maintenance program. In addition, the oil-potential capacity of the pool will be maintained at a relatively higher level than if nonunitized primary operations had continued. Methods for estimating increases in recovery from secondary over primary operation vary in procedure and reliability because, in most instances, economic factors and reservoir performance cannot be predicted with desired accuracy. However, the reservoir data for the Jones sand pool are complete enough to invite an attempt to estimate the expected increase in recovery from the pool.

The procedure to be described briefly is an attempt to apply strict theory to approximate the future behavior of the pool from past performance. The weaknesses in the procedure will be apparent, yet the departure from accepted facts is not too great for the procedure to have some merit as a means for comparing expected recovery from two methods of producing a reservoir of the purely depletion type.

The material-balance equation applied to estimate oil initially in place and shown to adequately represent the past performances of the Jones sand pool, may be used to predict future reservoir pressures as a function of future accumulated production based upon the indicated volume of oil in place. This can be done if future producing gas-oil ratios can be estimated.

The producing gas-oil ratio of a reservoir at any time is a function of the average reservoir flowing pressure, the solubility of reservoir gas in oil, the ratio of viscosities of reservoir oil to gas, and the "effective" permeability ratio of gas to oil as fixed by the physical character of the reservoir rock and its associated liquid saturation.

Rather than resort to a laboratory test on core specimens to evaluate the effective permeability ratio, the assumption was made that the producing gas-oil ratio of the Jones sand pool from discovery to Feb. 15, 1941, established the effective permeability ratio of gas to oil as a function of the average reservoir liquid depletion of the pool. Accordingly, the gas-oil ratios in that period were used to calculate "apparent" effective permeability ratios of gas to oil. When these ratios were plotted on a semilog paper against corresponding residual reservoir liquid saturation, a nearly linear relation was found, which was extrapolated into the saturation range of future recovery. After the effective permeability ratios of oil to gas as a function of accumulated reservoir liquid produced were evaluated in this manner, a trial and error simultaneous solution of the fundamental gas-oil ratio equation with the material-balance equation permitted an estimate of future gas-oil ratios and reservoir pressures under continuation of the primary operation and under the present secondary gas-injection program.

This procedure permitted computation of the dashed-line curves of Fig. 16. The gas-oil ratio and reservoir-pressure curves for continuation of the primary operation have trends usually associated with gas-drive pools. The ultimate recovery by continuation of primary operation might have been approximately 34 million barrels (30 per cent recovery). With 90 per cent return of produced gas under the secondary operation, the gas-oil ratio will steadily increase to a chosen economic limit of 20,000 cu. ft. per barrel, at which point the reservoir pressure is expected to be about 600 lb. per sq. in. and the ultimate recovery approximately 54 million barrels. On the basis of such an analysis, the estimated increased ultimate recovery due to the unitized gas-injection program is approximately 20 million barrels.

Gas Conservation

The saving for future sale of the natural gas that would otherwise be wasted in the field is an important element in the unitized operation. The volume of gas remaining in the reservoir after 54 million barrels recovery at 600 lb. per sq. in. reservoir pressure should be about 18 billion standard cubic feet.

Savings in Equipment

Unit operation of the Jones sand resulted in the conservation of a large quantity of equipment. Four gas-lift systems represent the total Unit investment in artificial lift in the Jones sand and the pressure-maintenance program can be credited with saving the installation of pumps on about 140 Jones sand wells. Instead of 62 leases equipped with tank batteries and separators, the Jones sand is now produced into eight consolidated tank batteries and a large amount of such surface equipment has already been salvaged.

Shut-down Wells

One of the unique features of the Jones unit operation is the fact that fewer than 50 of the 140 unit wells have been used each month to produce the allowable oil. In November 1942 the number of wells produced was 37 (Fig. 15). About 50 unit wells have been completely shut in since the unit was formed. These are in the east half of the field principally. A question immediately arises in connection with well spacing. Could the Jones sand at the Schuler field have been as successfully developed with fewer wells? At present it appears that one well to 40 or more acres would have served the unit operation adequately; but judgment in this matter will be more certain after the west area is brought to a higher stage of depletion and production is again taken from the entire area of the pool.

Cotton Valley Unitization

Extension of the Jones sand unit to include the undeveloped Cotton Valley sandstone within the then unitized area was a definite conservation measure. Jones sand wells temporarily or permanently plugged back will permit recovery of a substantial volume of oil from reservoirs that could not be developed economically in any other way.

Cost of Reservoir Data

The Schuler operations are important as an example of the benefit that may be derived from the application of accepted modern petroleum engineering practices. The Schuler unit is an example of what might be accomplished generally if sufficient care were exercised in obtaining detailed reservoir data.

Petroleum engineers are often called upon to justify the cost of extended programs of reservoir study, since good and sufficient reservoir data often involve large investments. The justification of such data cannot often be readily or immediately established. Executives charged with the responsibility of making prudent investments are inclined, therefore, to forego the opportunity to obtain complete reservoir engineering data on new pools. Unfortunately, the opportunity exists but once. The decision to take and analyze cores, obtain reservoir pressures, and provide other well-test information is a most critical one.

Schuler probably has been the most exhaustively studied of all reservoirs. A careful estimate of the total expenditures for cores and core analyses, electric logs, monthly reservoir-pressure surveys, bottom-hole samples, field tests, and laboratory work, including office expense attendant on the distribution of reports—all regarded as expenditures for reservoir study—average to this date about $1800 per well drilled. For the 146 wells this sum is about $263,000. In terms of total money, it is a large sum; perhaps an unjustifiable investment to those not enthusiastic about the ultimate value of reservoir data. Expressed in terms of a primary oil reserve of 35 million barrels, this investment at Schuler amounted to $0.007 per barrel.

The value of that investment was returned to the operators of the Jones pool as savings in dry holes not drilled. Moreover, the reservoir data were almost entirely responsible for the clear understanding of the pool that led to the very successful unit operation and the sound design of the gas-injection plant and equipment. In addition, the unit operator has a fund of information available to guide the usual rework and reconditioning operations associated with field work. The values so realized have returned the investment in reservoir study with substantial profit if such an investment should have to be charged as a separate expense under accepted modern engineering practice.

Acknowledgments

It is impossible to acknowledge the contributions of the many individuals of the several companies who have contributed directly or indirectly to the engineering study of the Schuler field. The contributions of those many engineers and geologists are recognized by acknowledgments to: the Schuler Unit Operator's Committee: Messrs. T. M. Martin (Lion Oil Refining Co.), C. P. Dimit (Phillips Petroleum Co.), O. G. Murphy (Marine Oil Co.), R. C. Knox and C. H. Murphy, Jr. (El Dorado, Ark.); members of the Schuler Unit Engineering Committee: Messrs. John Catlin (Lion Oil Refining Co.), J. T. Bachtel (Marine Oil Co.), and C. H. Murphy, Jr. (El Dorado, Ark.); Mr. J. E. Howell (Lion Oil Refining Co.), in charge of Schuler unit operations.

Acknowledgments are also due to Mr. D. R. Knowlton, Director of Production, Office of the Petroleum Administrator for War, and, to Mr. Frank Richardson, U. S. Army, for contributions during their association with the unit operation.

Appreciation is expressed to members of the Reservoir Engineering and the Production Research Sections of the Phillips Petroleum Co., whose reports and studies of the Schuler field were used in the preparation of this paper. Mr. Warren B. Weeks, Phillips Petroleum Co., kindly contributed the geologic maps and cross sections presented.

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APPENDIX

The material-balance equation as it applies to the Jones sand pool can be placed in the following convenient form because the solubility-shrinkage curves can be expressed as linear functions of pressure above 500 lb. per sq. in. abs.:

$$n = \frac{N[r - 18.65 + 0.045P_1 + 5.38 \times 10^{-6}P_1{}^2] - (0.0672)(W - w)P_1}{[P_0 - P_1][0.0334 - 5.38 \times 10^{-6}P_1 + m(1 + s_0)(0.0672)]}$$

Wherein substitutions for a time period from t_0 to t_1 are made as follows:

N = pipe-line oil produced, bbl.
r = average net produced gas-oil ratio, cu. ft. per cu. ft.
P_0 = static reservoir pressure at t_0, lb. per sq. in. abs.
P_1 = static reservoir pressure at t_1, lb. per sq. in. abs.
m = ratio of reservoir space filled with free gas to space filled with reservoir liquid at time t_0.
$(1 + s_0)$ = reservoir-liquid volume factor at time t_0.
W = volume of water encroached into reservoir at time t_1, bbl.
w = volume of water produced at time t_1, bbl.
n = volume of residual oil initially in place, bbl.

The oil-in-place calculations of Table 2 were obtained with discovery as the initial time and setting $m = 0.03$, $W = 0$ and $w = 0$. The pressure data were those observed at 7300 ft. subsea converted to 7340 ft. subsea, considered to be the average depth of the saturated section. Volumetrically averaged pressures were used, with the thought that they would most nearly approximate the true static pressure of the reservoir.

The solubility data of the first bottom-hole samples can be represented by:

$$S = 0.0334P + 18.65, \text{ cu. ft. per cu. ft.}$$

and the reservoir volume factor by:

$$(1 + s) = 8.00 \times 10^{-5}P + 1.168$$

above reservoir pressures of 500 lb. per sq. inch.

DISCUSSION

J. F. REDMOND,* Houston, Texas.—Dr. Kaveler has given a very instructive paper on one of today's most interesting problems of reservoir performance. He and his associates should be thanked for their effort in working up these data and particularly for discussing them here today, thereby giving the industry in general the benefits of at least one quarter of a million dollars spent in research. I am sure that it will be agreed that that expenditure is not large considering the size of this project and the value received, nevertheless it is a sum that reflects an engineering study of proportions seldom attained in the past.

The advantages of unitization and pressure maintenance are inescapably illustrated by the more uniform reservoir pressures and the decrease in rate of reservoir-pressure decline, causing a saving of artificial-lift equipment and a reduction in the gas-oil ratio. These points are especially significant when it is realized that approximately 50 per cent of the ultimate, by natural production, had already been produced at the time unitization was effected.

Dr. Kaveler has concluded that without pressure maintenance the ultimate recovery would have been approximately 35 million barrels, which for depletion conditions would seem to be entirely reasonable. Pressure maintenance is expected to increase this quantity by some 20 million barrels. This figure is less substantiated than the first but it seems certain that appreciably more than 35 million will be obtained. There is no doubt that the beneficial effects of pressure maintenance upon ultimate recovery will depend upon the relative permeability characteristics of the formation; the physical properties of the oil and gas; the amount of gas returned to the formation; and the production gas-oil ratio. It would be a rare case, however, for which these data would be known with sufficient accuracy to be used in flow equations for determining the increases in recovery by pressure maintenance. Dr. Kaveler has nicely sidestepped these difficult points by using the reservoir's past production behavior and material-balance calculations to determine the expected gas-oil ratio as a function of future production. This method may have been used by some production engineers but I think this is the first time that it has been suggested publicly and applied to an actual problem of reservoir performance.

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* Shell Oil Company.

There is one conclusion in the report which I believe is not quite well founded. That is Dr. Kaveler's interpretation of the material-balance calculations for indicating the presence of a water drive. In Table 2 he has shown the calculated volumes for the oil initially in place at successive stages of production. These values were calculated by assuming no water encroachment. As Dr. Kaveler pointed out, these values are correct if they remain constant. Under such conditions the basic assumption is correct, since then they show that there is no water encroachment. If the values increase continuously in each successive stage of production, water encroachment is indicated, definitely but not quantitatively.

The report directs attention to the upward trend of the calculated volumes of oil in place, beginning with unit operations. It was stated also that the increase was not as large as would be expected if water encroachment existed, and therefore the significance of the trend was discounted.

I might recall for you that this trend began at a volume of approximately 109 million barrels and has increased steadily during the past 18 months to approximately 120 million barrels, an over-all increase of 10 per cent.

For the purpose of analyzing the meaning of the upward trend of the calculated volumes of original oil in place, an attempt could be made to determine quantitatively the rate of water encroachment that would account for the reservoir's performance. That might be done by selecting periods in which the reservoir pressure remains constant. During such periods, and when strictly depletion-type reservoirs are considered, the reservoir volume of the gas and oil produced must be equal to the reservoir volume of the gas returned. If these volumes are not equal, other reasons must be found to explain the filling in of the entire pore space vacated by the produced oil and gas.

Several such periods exist between: (1) August through December 1941, when the average volumetric pressure dropped from 1533 to 1528 lb. per sq. in.; (2) February through July 1942, when the volumetric pressure dropped from 1521 to 1510 lb. per sq. inch.

For the period between Feb. 1 and July 31, 1942, when the maximum pressure variation on either the areal or volumetric basis was less than 13 lb. per sq. in., the reservoir volume of the produced oil and gas was approximately 9 million barrels, while the reservoir volume of the returned gas was only 6¾ million barrels. This leaves a deficiency of 2¼ million barrels, which must be equivalent to a volume of water entering the reservoir during the 182 days. At this rate, the total water influx to July 31, 1942, is estimated at around 13,000,000 bbl., a not insignificant figure compared with the total amount of oil produced, 23,700,000 bbl. If no water does enter the reservoir, an error of approximately 25 per cent in the volumetric calculations must be accepted.

This point may be checked in another manner. It may be assumed that there is no water drive but that the production during the period mentioned was due to the expansion of the fluids in the reservoir alone on account of the 13 lb. pressure drop. And not to be conservative in our estimates, it will be assumed that the pressure did actually drop 20 lb. per sq. in. and that the reservoir originally contained at least 125 million barrels of tank oil. Under such circumstances the fluids remaining in the reservoir could expand not more than one million barrels, still leaving a volume of at least 1¼ million barrels to be filled by encroaching water.

If these calculations of water influx are to be ignored and the reservoir to be considered a strictly depletion type, large errors in material-balance calculations must be accepted. *If* such large errors do exist, would they not *also* invalidate any calculations by this method of original reservoir volumes, or of the increased future recoveries under pressure-maintenance operations as reported in this paper? If such large errors cannot be accounted for, the reservoir is not entirely of the depletion type.

These considerations are important, for no concrete conclusions can be drawn as to the recovery efficiency of this reservoir and the influence of pressure maintenance upon ultimate recovery until the presence and effectiveness of the possible water drive is accounted for.

Finally, I cannot but feel that Dr. Kaveler's statement that "at the present time all of the outside wells about the entire flank of the Jones pool produce water in amounts up to 60 per cent of the total liquid produced," and the rate of increase in water production, confirm the existence of a water drive, which was indicated by the results of the calculations.

W. A. Bruce,* Tulsa, Okla.—It is believed that the behavior of the gas-oil ratio of this pool is particularly significant. The departure of the curve of gas-oil ratio from the theoretical one indicated by curve 4, Fig. 16, is believed to be due to gas-oil segregation. If this is true, the future gas-oil ratio of the pool will be as much a function of the method and rate of production as it will be a function of the field calculated permeability relationships referred to by the author.

The relationship between saturation of oil and relative permeabilities to oil and gas is not linear, consequently any attempt to compute an average gas-oil ratio on the basis of relative permeability would depend upon the distribution of oil saturation as well as the average saturation itself. If the effective relative permeability values were determined on the basis of volumetrically determined oil and gas saturation in the reservoir, and the oil and gas saturation distribution that existed at the time the determinations were made from field data, these permeability values projected on other saturation distribution would not be applicable.

Obviously, if the pool is to be operated at its highest efficiency, and gas-oil segregation continues to be a major factor, the same distribution of saturation will not exist as did prior to unitization. It was this condition prior to unitization, during which period the rate of pressure drop was so rapid that gas-oil segregation was not an important factor and the gas saturation probably had a fairly uniform vertical distribution, upon which the author based his calculations of the permeability relations. Consequently, if there is a significant rate of gas-oil segregation and a correspondingly large variation in the vertical distribution of gas saturation, it should be accidental if the gas-oil ratio follows the curve 4 predicated upon no gas-oil segregation.

It is entirely possible that if the rate of oil production is greatly increased, the gas-oil ratio of the pool would rise above curve 4, whereas it is possible, by decreasing the pool production rate of oil, to reduce the gas-oil ratio below its present figure.

Another item of considerable importance from a standpoint of reservoir engineering is the reduction in number of wells necessary for the production of the pool allowable. It is noted that in November 1942 the number of wells producing was 37, or an individual production rate of over 300 bbl. per well per day. This operation led to a lower gas-oil ratio than when the pool was operated with 146 wells, with an average production less than 100 bbl. per well per day.

It is believed that even now a valuable lesson can be drawn concerning well spacing. The operators seem to have found that a well density of one well to 20 acres is not necessary and, furthermore, that some spacing wider than 40 acres seems to be indicated as being sufficient to exploit this reservoir.

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* The Carter Oil Company.

A Study of the Smackover Limestone Formation and the Reservoir Behavior of Its Oil and Condensate Pools

By W. A. Bruce,* Junior Member A.I.M.E.

(New York Meeting, February 1944)

Abstract

Studies of reservoir behavior of 12 Smackover limestone oil and condensate pools are presented. Buckner, Midway, McKamie, Magnolia, Mt. Holly, Schuler (Reynolds) and Village are treated in considerable detail and subjected to analysis with an electrical device for analyzing reservoir behavior. Results and comparisons of these analyses are presented.

In addition to these reservoir-behavior studies, an attempt is made to assemble transmissibility and storage data on the Smackover limestone formation from cores and logs taken in dry holes and producers. This together with the behavior of individual reservoirs leads to a better understanding of the formation as a porous aquifer.

The ultimate purpose of this type of study is to improve predictions concerning the future behavior of these pools in such a system. Predictions are presented for several pools.

Introduction

In 1937 the Phillips Petroleum Co. drilled its J. D. Reynolds No. 1 to the Smackover limestone formation at Snow Hill, Arkansas. This well found oil in the porous, permeable, upper part of the Smackover, thereafter referred to as the Reynolds lime. Since then, six oil pools and six condensate pools have been discovered in the Reynolds lime, and more than 75 dry holes have explored parts of this formation.

By the first of 1943, 44 million barrels of oil and 83 billion cubic feet of gas had been withdrawn from the various reservoirs. The original reserves estimated by the Arkansas Oil and Gas Commission were 342 million barrels of oil and 1200 billion cubic feet of gas.

So far all of the production has been from anticlinal structures, most of which are asymmetric and have their axes roughly perpendicular to the dip of the formation top. This is indicated in Fig. 1, which shows the pools, dry holes drilled, and contours on top of the Smackover.

These pools are of particular interest for reservoir-behavior studies because the production and drilling has been controlled, and in most cases the records of reservoir data are complete. In addition to the excellent production and pressure information available, more than one half of the wells drilled were cored and all of them were electrically logged. All of the pools show evidence of water drive.

While this paper is in a sense a collection of reservoir-behavior studies for several different pools, there has been an attempt to go one step further and to show the importance of the formation as a porous continuum or a single aquifer in which the withdrawals of fluids from any pool has an important effect on the behavior of all of the pools. An effort will be made to show that the water drives of these pools are dependent upon a much larger area of the Smackover limestone than that occupied by the petroleum accumulations.

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* The Carter Oil Co., Tulsa, Oklahoma.

SMACKOVER FORMATION

The Smackover formation, for the most part of the area under consideration, lies between the Eagle Mills red beds and salt and the Buckner anhydrite and red beds. Imlay[1] states that in southern Arkansas the Smackover is divisible into two members, of which the upper consists of oölitic to chalky limestone and the lower of dense limestone with dark argillaceous bands. Warren Weeks,[2] in discussing the geologic column at Schuler, writes:

> The cap rock, which is the top of the Smackover formation, and which immediately overlies the porous zone, varies in thickness from 2 or 3 ft. in the southeast part of the field to approximately 15 ft. in the northwest sector. It consists of hard, dense limestone with streaks of calcareous shale in the upper part, where it is thickest. The color of the

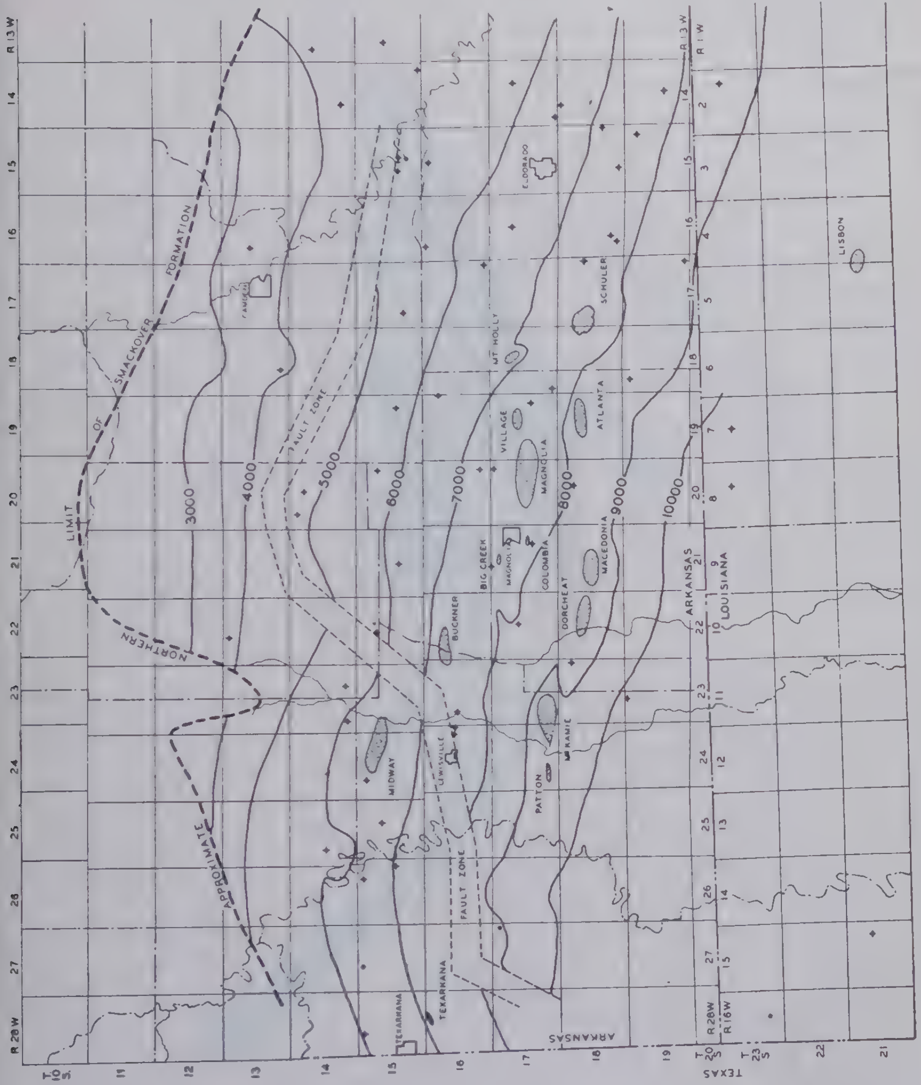

FIG. 1.—REGIONAL MAP OF SMACKOVER AREA.
Showing estimated areal extent of pools and contours in feet subsea on top of the Smackover.

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[1] References are at the end of the paper.

limestone varies from tan to gray. The texture is cryptocrystalline; however, a faint vestige of oölitic structure can be recognized.

The underlying porous oölite consists of typical concentrically grown spherical oölites, ranging in size from very fine to coarse and with a few pisolites the size of a small pea. Throughout most of the zone the oölites are only very loosely cemented, resulting in high porosities and permeabilities.

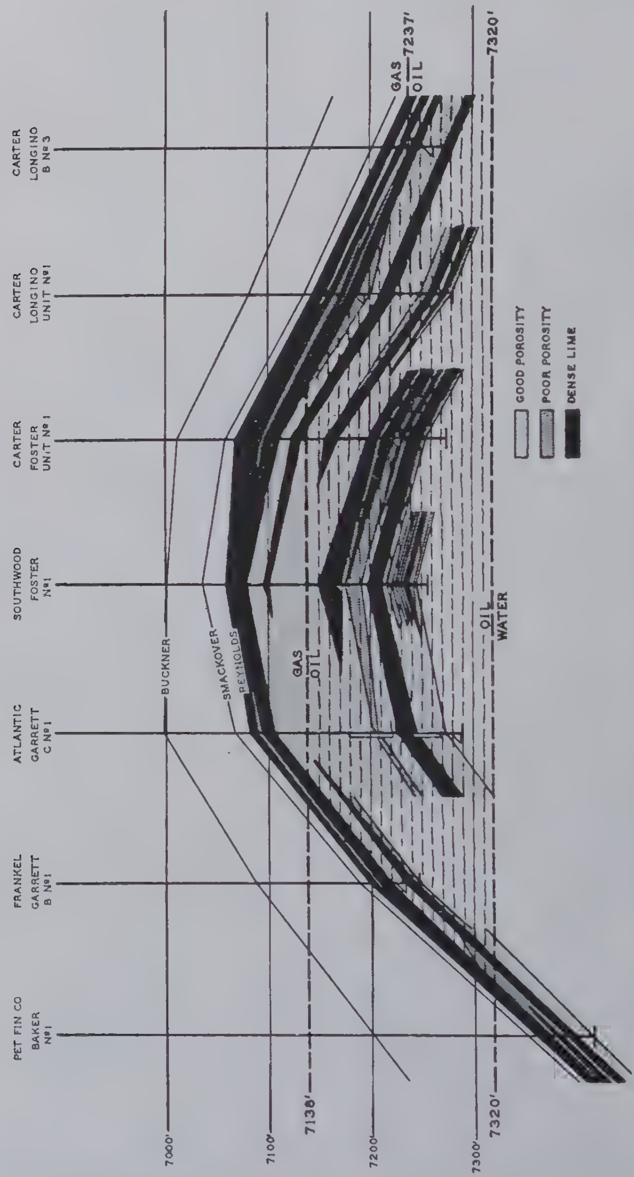

FIG. 2.—NORTHWEST-SOUTHEAST CROSS SECTION IN THE EAST HALF OF THE MAGNOLIA POOL.

These characteristics seem to be present in all the pools with variations in thickness of the cap rock from zero to over 50 ft. At Magnolia there is evidence of scattered carbonaceous material, possibly bitumen.

The Reynolds zone is broken here and there by lenticular strata of dense lime, which varies in thickness up to 25 ft. and which has a texture similar to the cap rock described above. These strata usually are not of sufficient extent to prevent the vertical movement of fluids over the area of an entire pool.

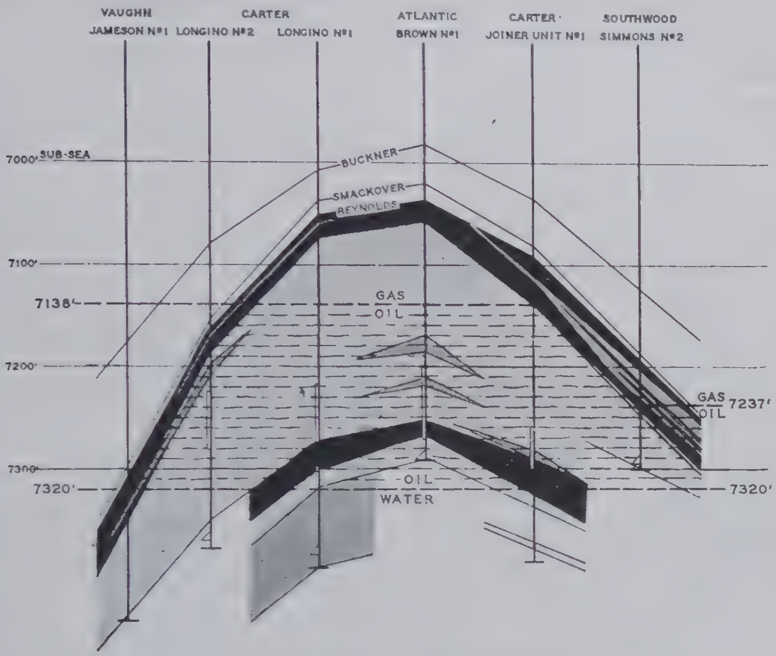

FIG. 3.—NORTH-SOUTH CROSS SECTION NEAR CENTER OF THE MAGNOLIA POOL.

Fig. 2, which is a diagonal NW-SE cross section across the east half of Magnolia, shows the cap rock and strata of dense lime. This may be contrasted with the extent of good porosity across the center of the pool shown in Fig. 3.

Most of these pools seem to have better over-all permeability near the center or top of the structure, from which it may be inferred that the permeability may be lower in the aquifer between pools than in the pools themselves. This porous part of the Smackover is at least 100 ft. thick with the maximum so far discovered of over 300 ft. at Magnolia. Thigpen[3] shows thicknesses of the entire upper member ranging from 280 to 500 ft., but all this is not porous.

In the area of production indicated by Fig. 1, and with the exception of the major fault zone, it is believed that the formation is such that no two areas are cut off from each other as far as the migration of fluids is concerned.

The Smackover extends from the unconformity, which is the limit on the north, indefinitely into Louisiana on the south. The Smackover lime covers most of the East Texas Basin, North Louisiana, South Arkansas, south of the line of truncation and extends across Mississippi into Alabama. It is not known whether this formation has porosity over all this area; however, porosity has been found in Limestone County, Texas, and several miles east of Schuler, Arkansas, and it is believed to lie in a band at least 30 miles wide between these points.

There is no known outcrop, nor is it likely that water entered or left this formation after Cretaceous time. The water analyses and hydrostatic conditions indicate that there may have been no appreciable movement of water after deposition. Thus, here is a picture of an isolated body of porous, permeable limestone 100 to 300 ft. thick and covering from 10,000 to 20,000 square miles filled with an almost saturated brine that was partially displaced in some of the high spots by petroleum accumulations.

The brine density from all pools is approximately the same and averages 1.22 sp. gr., which corresponds to 0.52 lb. per sq. in. per foot.

The area of immediate importance to the known production is about two million acres and probably contains more than 200 billion barrels of water. The known oil in place in the proven reservoirs originally was 700 million barrels, and the gas in place was 600 million barrels. To displace 50 per cent of these hydrocarbon fluids by water will mean an average drop in water pressure of from 200 to 500 lb. This will mean that the pressures at the various pools can be expected to be considerably affected by the production from the total area. This effect may be considered as interference superimposed on the expected behavior of each individual pool.

So far the interference or competition among pools for the common water supply has not been clearly shown because of the large time lag in pressure-flow relations throughout the formation, and because the total water movement into pool areas has been only 50 million barrels.

The fluids in this large porous and permeable blanket were, prior to petroleum exploitation, under pressures that varied with the subsea depth. A plot of these pressures versus depth is shown in Fig. 4. The slope of this hydrostatic line is about the same as the brine density shown above. It is believed that information prior to extensive exploitation is sufficient to establish the validity of this relationship of pressure versus depth, and that from now on original pool-pressure values that fall below this line will represent evidence of interference. A measurement at the recently discovered Columbia pool in sec. 23, 17 S., 21 W., showed 100 lb. drop from its expected hydrostatic pressure.

Adaptability of Analysis to Reservoir Behavior of Smackover Lime Pools

Several mathematical methods[4-6] of analyzing reservoir performance have been developed, and now analyses can be made by an electrical device[7] referred to hereafter as the Analyzer. All of these methods depend upon the assumptions of a certain degree of homogeneity in the system to be studied, and upon knowledge of certain geologic data.

If the porous continuum in which these reservoirs are found were an infinitely extensive, homogeneous, continuously permeable, and uniformly thick blanket formation, the future water influx into all of the pools could be calculated precisely and the interference could be established exactly from the behavior of the pools to date, with the aid of the analyzer. However, this formation is not uniform nor homogeneous and modifications of the analysis must be made to allow for heterogeneities and boundary limits. Several factors tend to simplify these modifications.

1. The limits of this formation are such that the behavior of most of the pools for the next 10 years will be as though no limits existed.

2. For most pools the exact location of the limits of the porous zone is of so little importance that only slight error should result from assumptions necessary.

3. Since rate of water influx is almost directly proportional to average permeability, it is necessary to know permeability with reasonable accuracy, but if the formation is permeable to any extent, an average value can be determined by a

short history of the pool behavior of several pools.

4. Major discontinuities, such as regional fault zones, have been located and can be accounted for by proper theoretical adjustment.

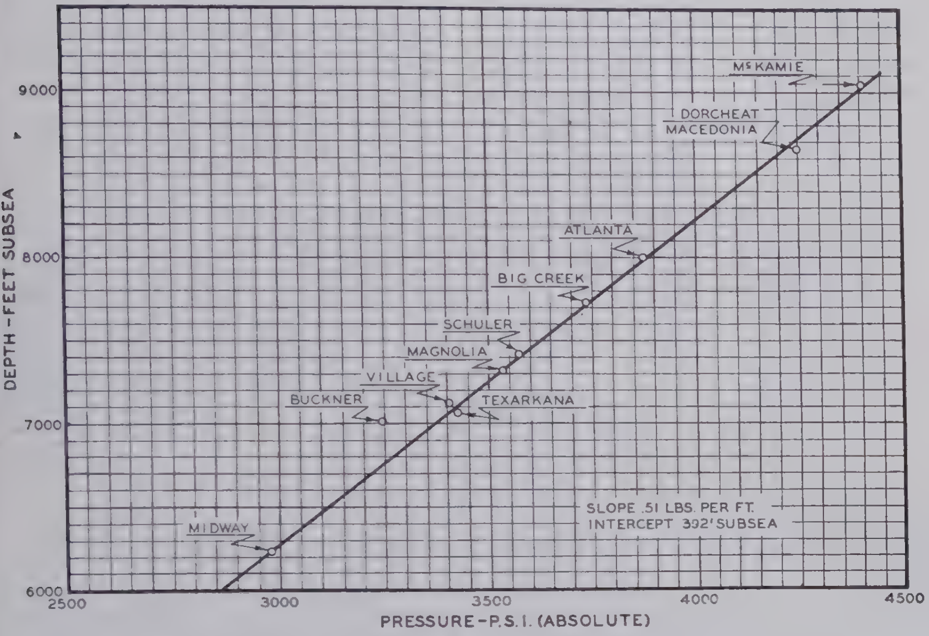

Fig. 4.—Original pressures in Smackover pools versus depth. Pressures are corrected to water-table level.

5. Variations in effective thickness or permeability within the limits have been shown by electric model experiments to average out unless the variations are progressive in one direction or are over all of some large area, or in case there are areas of total impermeability entirely surrounding a pool.

Therefore, the two main problems of analysis are to find the effective values of permeability and compressibility through the interpretation of reservoir performance and to identify and correct divergences caused by large-scale barriers anywhere in the formation or small barriers very near a pool or surrounding a pool. The first problem is solved automatically in the process of an analysis. For the second, something can be done by analysis but geologic information also is needed to make the interpretation of the reservoir behavior accurate.

It is certain that errors will arise when there are unknown or unaccounted for barriers to flow. The foregoing is meant to show only that these errors should not be as large as might be expected from the heterogeneities known to exist. Such barriers to flow very near a pool will cause too low a pressure prediction. Barriers about 10 miles from a pool will cause too high a pressure prediction. Scattered small barriers will not materially affect a prediction.

In the foregoing discussion it has been indicated that difficulty will be encountered and errors are to be expected in an attempt to analyze the reservoir behavior of these pools, either mathematically or with the analyzer. It is clear, however, that many of the possible errors in the analysis can be eliminated by use of the analyzer largely because known barriers to flow can be properly accounted for.

It is apparent that one of the limitations in an analysis is the lack of complete geologic data. In particular, one of the limitations is the incompleteness of information concerning the transmissibility of water through the Reynolds zone in the areas between pools. While some of the information concerning transmissibility has been obtained from dry holes drilled, in other instances the possibility of using this information was not considered by geologists on the job and consequently only fragmentary data exist. It is believed that future drilling will produce data that will give a more complete picture. At the same time, the development of the pools already discovered should contribute to the better understanding of this porous, permeable formation, so that within two or three years a much better analysis of this problem can be made than is presented at this time.

TABLE 1.—*Data Obtained with Analyzer*

Pool	Producing Wells	Estimated Number of Acres	Original Reservoir Volume, Million Bbl.		Estimated Average Laboratory Permeability, Md.	Estimated Average Laboratory Porosity, Per Cent
			Gas Zone	Oil Zone		
Atlanta	22	1,000	2.4	23.8	1,276	15.0
Big Creek	1	200	12.0		250	12.5
Buckner	28	1,610		43.3	50	20.0
Dorcheat	23	2,130	80.0	21.8	155	14.0
Macedonia	17	2,250	100.0	24.0	229	14.0
Magnolia	116	5,600	65.0	360.0	1,500	17.0
McKamie	17	2,800	288.6		400	17.0
Midway	37	2,400		180.0	145	21.3
Mt. Holly	5	360	11.3	10.5	1,130	20.0
Schuler	15	1,200	4.7	34.4	1,500	18.5
Texarkana	1	240	5.0		174	14.0
Village	12	640	11.3	18.8	2,000	20.0

METHODS OF ANALYSIS AND PREDICTION

The methods of using the analyzer for study of these pools and for predictions of pressure and water influx have been described.[7] The use of the analyzer for this purpose rests upon the analogy between the flow and storage of electric charge, and the flow and storage of reservoir fluids in the porous media of the reservoir. Electric currents, corresponding to the flow of fluids, are withdrawn from the condenser and resistor network that comprise the analyzer, in a manner that is analogous to the withdrawal of fluids from the various wells or pools. By comparison of the voltages obtained in the electrical device, and the pressures observed at the wells and pools, the over-all nature of the reservoirs and the continuous water-filled porous media in the neighborhood of these reservoirs can be determined.

Furthermore, if the analyzer is adjusted so that it will reproduce the pressure behavior of a pool or a well up to the present date, it can be relied upon to predict future pressures under any reasonable set of arbitrary producing conditions. In the event that water-influx data corresponding to assumed pressure conditions are desired, these too can be obtained.

Seven pools were studied with the analyzer; of these, Buckner, Magnolia, Midway, and Schuler were given the most detailed analysis. The factual data for these pools are shown in Tables 1 and 2. The constants expressing the nature of the aquifer surrounding the pools, and based entirely upon the performance of the pools, are shown in Table 3.

Water Influx

Direct measurements and calculations have shown that water is moving into all of the Smackover pools. At Magnolia over 23 million barrels of water have moved into the oil zone, and two million barrels have been produced with the oil. At Schuler, the water influx has been over nine million barrels and at Village an almost equal amount has been observed. The calculated accumulative water influx for all of these pools is shown in Table 2, and the water influx versus time for seven of the pools is shown as curves for individual pools.

Table 2.—*Data Obtained by Material Balance*[a]

Pool	Oil, Stock Tank, Bbl.	Gas Produced, M Cu. Ft.	Water Produced, Bbl.	Cumulative Water Influx, Million Bbl.	Pressure Change, Lb. per Sq. In. (Δp)	Water Influx, Bbl. per Day per Lb. per Sq. In.	Water Influx, Bbl. per Δp	Water Influx, Bbl. per Day per Lb. per Sq. In. per Acre
Atlanta...	3,321,658	4,345,696	229,047	5.49	425	11.9	12,900	0.012
Big Creek.	138,933	3,431,109	1,000	2.51	353	7.2	7,100	0.036
Buckner...	3,853,742	913,784	453,686	4.86	710	4.0	6,800	0.003
Dorcheat..	1,836,237	17,625,000	5,000	2.10	930	7.5	2,300	0.004
Macedonia	579,577	7,017,000	3,000		430		•	
Magnolia..	27,998,000	25,299,000	2,137,000	24.50	450	41.8	54,400	0.007
McKamie.	1,746,883	13,148,397		3.34	245	17.2	13,600	0.006
Midway...	2,225,258	580,803	52,363	1.84	240	18.6	7,700	0.008
Mt. Holly.	219,909	1,324,241	29,758	0.69	156	8.8	4,400	0.024
Schuler...	4,396,000	6,377,000	2,096,000	10.15	225	45.4	45,100	0.038
Texarkana	21,995	650,000		0.55	89	17.4	6,200	0.073
Village....	1,801,600	7,930,000	518,000	8.15	170	25.2	47,800	0.038

[a] Production data are as of June 30, 1943.

Table 3.—*Data Obtained with Analyzer*[a]

Pool	Arbitrarily Assumed		Determined by Analysis				
	L/N	MN	L	N	M	$k\frac{b}{v}$	cb
Atlanta................	0.01	0.1	0.354	35.4	0.0028	2.55	0.00061
Buckner................	0.01	0.1	0.1112	11.12	0.0090	1.28	0.00018
Midway................	0.00867	0.2775	0.1781	20.2	0.0137	3.45	0.00031
McKamie................	0.01	0.2	0.575	57.5	0.0035	4.14	0.00044
Magnolia................	0.001496	0.06	0.1367	91.3	0.0007	6.57	0.00231
Mt. Holly................	0.02	0.3	0.493	24.65	0.0122	1.78	0.00021
Schuler................	0.006	0.1	0.359	59.8	0.0017	4.32	0.00182
Average................						3.44	0.00058

[a] Assume $b = 100$ ft. and $v = 1.0$ cp., then average $k = 30$ md. and $c = 5.79 \times 10^{-6}$ bbl. per bbl. per lb. per sq. in.
L, M, and N are factors explained in the special report on the analyzer.
k = permeability, perms (1.127 times darcys). b = thickness, feet.
v = viscosity, centipoise. c = compressibility, bbl. per bbl. per lb. per sq. in.

In the calculation of water influx, various forms of the material-balance method were used. In each case, it has been assumed that volumes of oil and gas in place could be determined more closely from the fairly complete geological information available than by that form of the material-balance method in which the water influx and original oil in place are determined simultaneously.

In addition to this calculated water influx, there have been other indications that the pools in the Smackover have potential water drives. One of these has been the early appearance of water in edge wells and the continuous increase in percentage of water production. Another indication has been the rise in pressure associated with sizable reduction in production rate. This has been particularly noticeable at pools that were shut in for an interval of several days or more.

The Reservoirs

The most important factual data, concerning the reservoirs considered in this report, are contained in Figs. 5, 7, 9, 10, 12, 14, and 16. Other information of interest, or necessary for the study of these pools, will follow in a discussion of the individual pools, or will be found in Tables 1, 2, and 3.

Data on the behavior of hydrocarbons and detailed laboratory analyses are not shown in this report, but some of these data have been reported previously.[8] It has been found that the shrinkage of the oils in these various pools is remarkably similar, also that the curves for pressure-volume behavior of the various gases are much alike. For this reason it has been found possible to make up a chart for distillate-producing wells, which relates the barrels voided from the reservoir for a barrel of stock-tank distillate. The parameters for this set of curves are gas-oil ratio and bottom-hole pressure.

Magnolia Pool

The Magnolia pool[8,9] is the most important petroleum accumulation so far found in the Reynolds zone of the Smackover limestone. It is an elongated anticline with an areal extent of 5600 acres and a closure of over 270 ft. This pool has been producing about five years and has produced about one fifth of the ultimate recoverable oil. It is currently being depleted at the rate of about 4 per cent per year.

Pressure and production data, together with material-balance calculations, indicate a water drive. This is graphically shown in Fig. 5.

About 25 million barrels of water has moved into the pool to date and enough water may be available ultimately to flood 50 per cent or more of the 425 million barrels of the oil and gas zones.

Water seems to be moving into this pool from all sides, although local producing conditions make it seem that the water drive is coming in more from the southwest. This is believed to be due to well-completion practice and local porous conditions rather than to a general movement of water.

Core data at Village and near-by dry holes show that the permeability and porosity in the Reynolds limestone is good on the east side of Magnolia. The Carter Warnock-Spring and a Phillips dry hole, 3 or 4 miles north of Magnolia, showed good porosity for 100 ft. into the Reynolds. Big Creek and Columbia show poorer but definitely permeable formation to the west. A dry hole 5 miles south, and wells in the Atlanta pool, complete the ring of proven, porous and permeable oölitic limestone filled with salt water surrounding the Magnolia area.

It is concluded, therefore, from local and general conditions, and from the reservoir behavior, that for the analysis of the behavior of Magnolia, it is correct to assume no barriers to fluid flow other than the fault line north of the pool. It is possible that other barriers exist, but in view of the arguments set forth in the section on Adaptability of Analysis, it is believed that these barriers can be treated as scattered heterogeneities, which tend to diminish the effective permeability and therefore can be accounted for by operation of the analyzer. Therefore, the behavior of the pool is used to determine these average conditions and to interpret the values to be used for permeability and effective fluid compressibility. These data are shown, together with similar information on other pools, in Table 3.

Because of the restricted withdrawal rates and the water influx, this pool may be considered as a water-drive pool. Analysis shows, however, that the pool

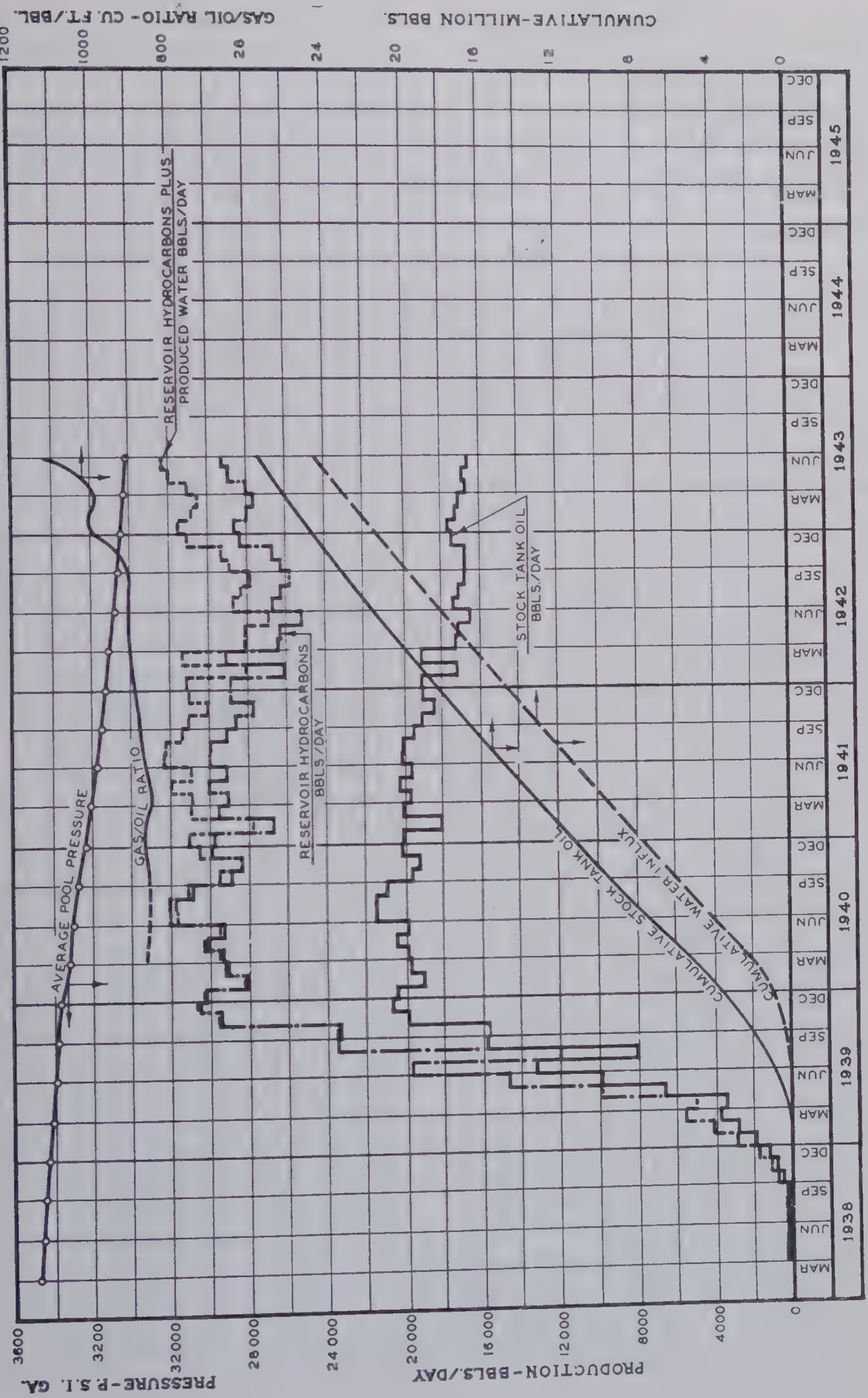

FIG. 5.—MAGNOLIA PRODUCTION AND PRESSURE DATA.

would become a dissolved-gas-drive pool within a year if the rate of withdrawal were increased from its present 4 per cent per year to 8 per cent per year.

The behavior of the pool is very sensitive to operating conditions. Various methods of operation could lead to three distinct types of behavior: (1) a dissolved-gas drive with a delayed gravity segregation would result if rate of oil withdrawal were permitted to go above 25,000 bbl. per day (7 per cent per year) and no gas return were made; (2) total flushing by water, including invasion of the gas cap, first by oil and then by water, would result from a combination of two factors of high gas-oil ratios (2000 to 3000 cu. ft. per bbl.) and moderate rates of production (10,000 to 20,000 bbl. per day). The end condition of this operation would be the flooding of the entire oil and gas zones by water sometime after 1975; (3) a combination of gas cap expansion and water drive would result from gas injection. The gas cap would expand from its original ⅙ of the total to a maximum of ⅓ of the original volume of the gas and oil zones. For this condition, injected gas would retard the invasion of water, and if 100 per cent gas were returned the original pool would be ⅓ occupied by gas and ⅔ by water. The end point of the oil-pool development would be a narrow zone of oil between gas and water. Behavior of individual wells at Village and Mt. Holly indicate that this zone at Magnolia could be narrowed to less than 10 ft. before serious operating difficulties developed.

The method most likely to be effective seems to be one of partial control of water and excess gas. Possibly the net water production will be held to 20 per cent and the pool gas-oil ratio will be held below 2000 cu. ft. per barrel. It is also likely that oil-production rates will be reduced gradually. An assumption of 3.2 per cent per year reduction in the oil-production rate seems reasonable.

For these conditions the gas cap will not show appreciable shrinkage for 5 or 10 years. It is estimated that the gas-cap shrinkage by 1960 would be 20 per cent, and that the gas cap would be completely invaded by oil before 1975. These and other conditions are indicated in Table 4.

TABLE 4.—*Results of Various Operations at Magnolia Predicted for* 1960

Case	Cumulative Oil, Million Bbl.	Pressure, Lb. per Sq. In.	Water Influx, Million Bbl.	Assumed Conditions[a]
1	146	2,650	120	100 per cent gas return; 20,000 bbl. per day, 20 per cent water
2	116	2,900	110	100 per cent gas return; rate reduced to hold pressure at 2900; 20 per cent water
3	94	2,400	175	Gas[a] 2000 cu. ft. per bbl.; water 20 per cent; production-rate decline 3.2 per cent year[b]
4	125	1,400	330	16,000 bbl. per day; uncontrolled gas and water

[a] The 100 per cent gas return is assumed to start in 1945. It is assumed in the fourth case that 2000 cu. ft. per bbl. would be reached by 1950.

[b] Present trend.

Fig. 6 shows graphically the assumed conditions and the analyzer pressure predictions.

If the gas cap is permitted to shrink, loss of oil seems to be inevitable. On the basis of the assumption that the gas cap now has an oil or condensate saturation of 3 per cent, the loss of oil in the gas cap at 65 per cent water-drive flushing efficiency will be 10 per cent of the oil produced, or about 14 million surface barrels. The alternative to standing this loss is to hold the gas-cap volume constant by control of gas-oil ratio or injection of gas. These operations themselves have potential hazards and losses, which, however, seem to be less than possible by the total water drive. This analysis leads to the conclusion that the gain in total recovery by cases 1 or 2 over cases 3 or 4 would be 12 per cent. This, together with the increased rates, might make gas injection economically desirable.

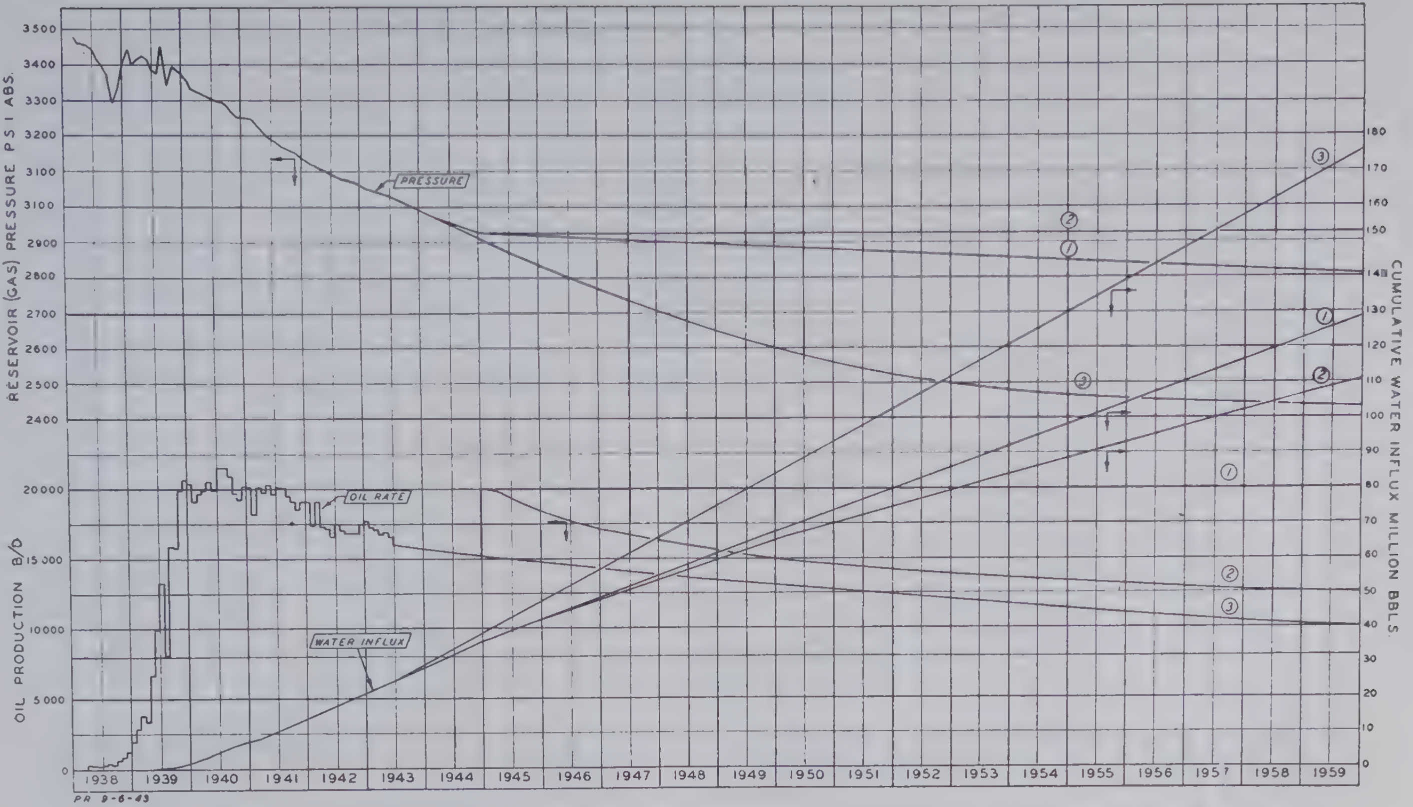

Fig. 6.—Assumed production rates, analyzer pressure predictions and calculated water influx, Magnolia pool.

For cases 3 or 4, it is likely that water will be drawn from great distance to the pool. Interference by all of the production within 10 miles will be a factor by 1960. This includes Atlanta, Big Creek, Dorcheat, Macedonia, Mt. Holly, and Village. These may total as much as 150 million barrels water influx by this date. On the basis of proved porous aquifer, the interference caused by this water movement would produce maximum pressure drop of 250 lb. per sq. in. at Magnolia by 1960. A minimum figure, including the unproved but estimated full extent of the Reynolds, is 75 lb. per sq. in. The predicted pressure drop caused by interference can be added directly to the predicted pressure drop caused by the development of the pool itself. Probably within two or three years this interference pressure drop can be evaluated more accurately. At present it cannot be more closely estimated for 1960 than the range 75 to 250 lb. per sq. in., and for that reason is not included in the pressure prediction for Magnolia or other pools.

VILLAGE POOL

The Village pool is a small, round anticline east of the Magnolia pool, and is separated from Magnolia by a sharp dip in structure, which goes about 300 ft. below the top of the structure at Village. The closure to the east is small, the pool having a 35-ft. gas zone and a 22-ft. oil zone. The oil reservoir is about one fourth depleted and the current production rate for oil is about 7 per cent of the original reserves per year.

Water is moving into the pool at about 4000 bbl. per day. The water influx and other pool statistics are shown in Fig. 7. The movement of water into the field and the sustained pressures have indicated a powerful water drive. Part of this is due to the small size of the pool, but a certain part is due to the high effective permeability in the region of the pool. It is not possible to evaluate accurately the effective permeability at Village because of the Magnolia interference, but it is estimated to be greater than for any of these pools.

The W. P. Phillips No. 1, in the center of the Village pool, was drilled to a total depth of minus 7290 ft. Core analysis showed porous oölitic limestone to minus 7207, or 80 ft. below the oil-water contact. The last 80 ft. below the porous oölitic limestone had slight permeability and 5 to 10 per cent porosity. It was characterized by recementation and had been described by the geologists as dense oölitic lime.

The Village pool is surrounded on all sides by wells that have shown indication of porous, permeable, salt-water-filled, oölitic lime 150 to 300 ft. thick. The water influx has been over 8 million barrels to date and it is likely that a sufficient amount of water will move in to keep pace with any reasonable production rate used. The total fluid necessary to invade the entire reservoir is less than four times that already having moved into the oil zone.

In respect to the methods of producing this pool, it seems that only two possibilities present themselves:

1. The pool can be completely produced by the displacing action of a natural water drive, possibly aided in a small way by water injection. In this case the oil will be forced into the original gas cap and eventually partially displaced by invading water. If the flushing action of water is 65 per cent, the pool recovery will be a maximum of 45 per cent, the loss resulting from oil lost in the gas cap.

2. The gas cap can be prevented from shrinking by the injection of gas. It is doubtful that this will gain more oil than the operation indicated above, because if the gas cap is held gas-oil ratios will rise to such a point that the operation may become uneconomic before 45 per cent of the oil has been recovered.

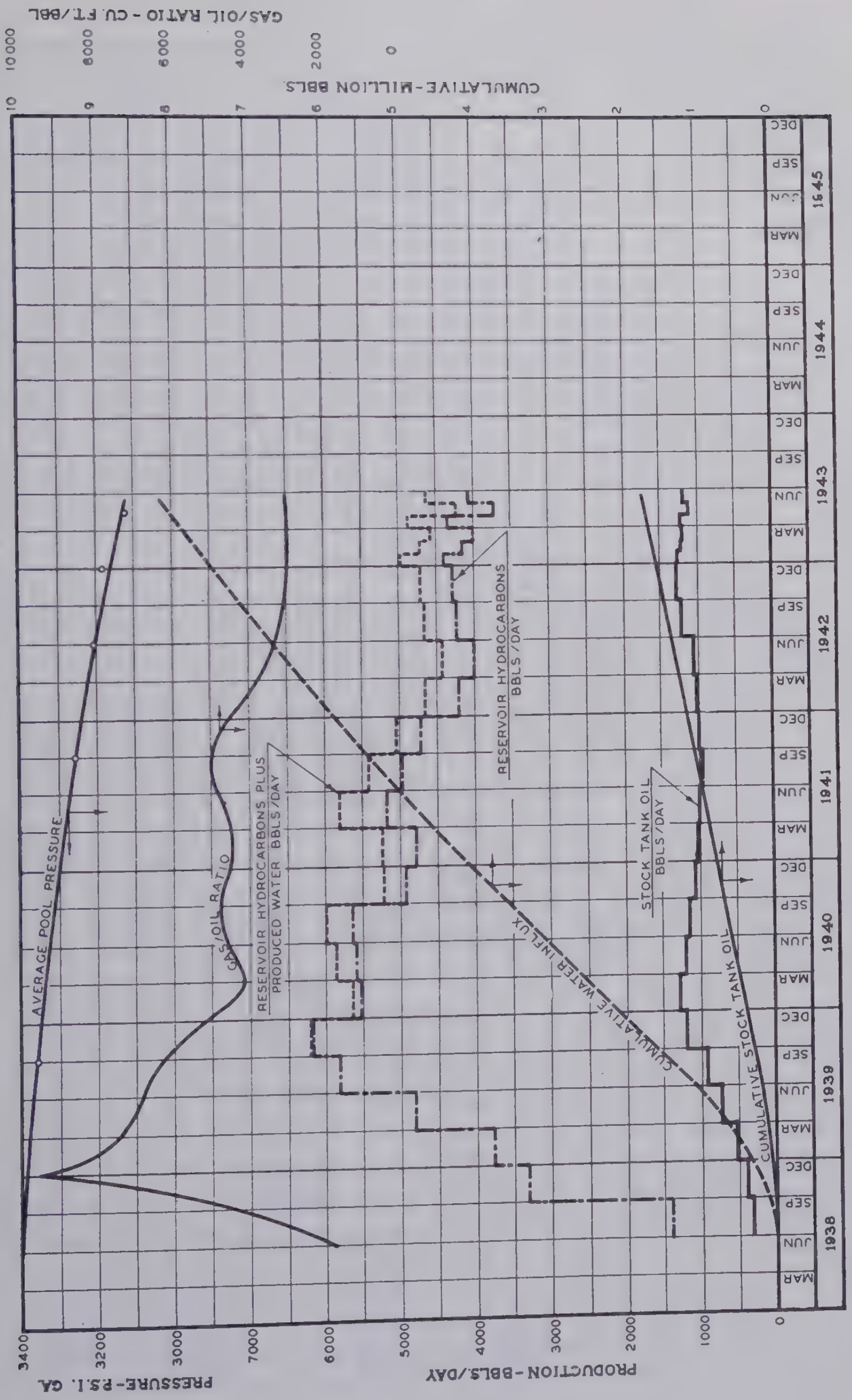

FIG. 7.—VILLAGE PRODUCTION AND PRESSURE DATA.

This pool is a border-line case, which would almost have to be tried before an answer could be obtained as to the economic advantage of preventing the gas cap from shrinking.

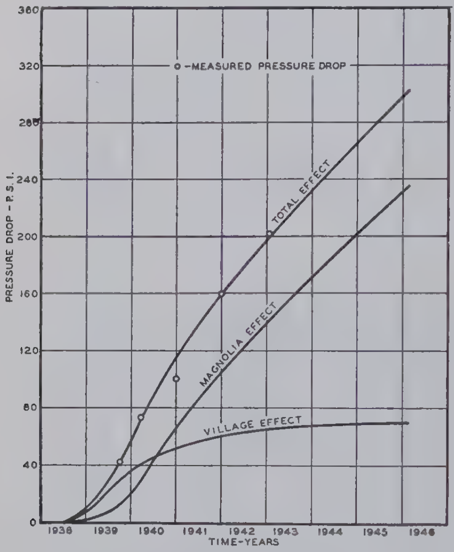

FIG. 8.—INTERFERENCE EXPRESSED IN TERMS OF PRESSURE DROP.

One important factor in the future behavior of the Village pool will be the interference caused by production at Magnolia. Fig. 8 gives an indication of an estimate of this interference. It is evident from this figure that the pressure behavior at Village is more affected by the operation of Magnolia than it is by the production of fluids at Village itself.

The method of analysis to determine the extent of this interference was based on a comparison of the behavior of this pool before the Magnolia pool had a chance of causing appreciable interference, with the behavior after the Magnolia pool effect had become predominant. The analyzer was used for the estimation of both effects.

MT. HOLLY POOL

The Mt. Holly pool, 5 miles east of Village and 7 miles northwest of Schuler, is a small oval anticline with a gas cap about the size of the one at Village, but with an oil zone only a little more than one half that of the Village pool. This pool is less than 2 years old and yet it is clear from its behavior that the pool has a water drive comparable to that found for the other pools in this area.

To date the oil production has been about 5 per cent of the pool's ultimate. The current rate of production is 20 per cent per year. Water influx calculations are shown in Fig. 9. As with Village, there seems to be no question but that sufficient water will be available to produce all of the oil in this reservoir and to provide water for pushing this oil through the gas cap. The loss of oil in the gas cap of this pool will be large. It is such a large factor that if the flushing efficiency is 65 per cent, the recovery factor will be less than 30 per cent, and if the flushing efficiency is 80 per cent, the recovery factor will be 40 per cent. It may be necessary to accept this low recovery because of the thin oil section and the small size of the pool.

It is likely that gas injection to prevent the shrinkage of the gas-cap will not be put into practice at Mt. Holly. Therefore, it seems that the recovery from this pool, although it has a good water drive, will be between 30 and 40 per cent.

Interference at this pool from other production in the area should be small, and, because of the other factors controlling the production and ultimate recovery, such interference as is possible will be of negligible importance.

SCHULER (REYNOLDS) POOL

The Schuler (Reynolds) pool[2] lies directly under the Schuler (Jones) sand pool. It was discovered in October 1937, by a well that originally was brought in as a gas well and that produced 2 billion cubic feet of gas before the underlying oil zone was discovered. The gas and oil of the pool

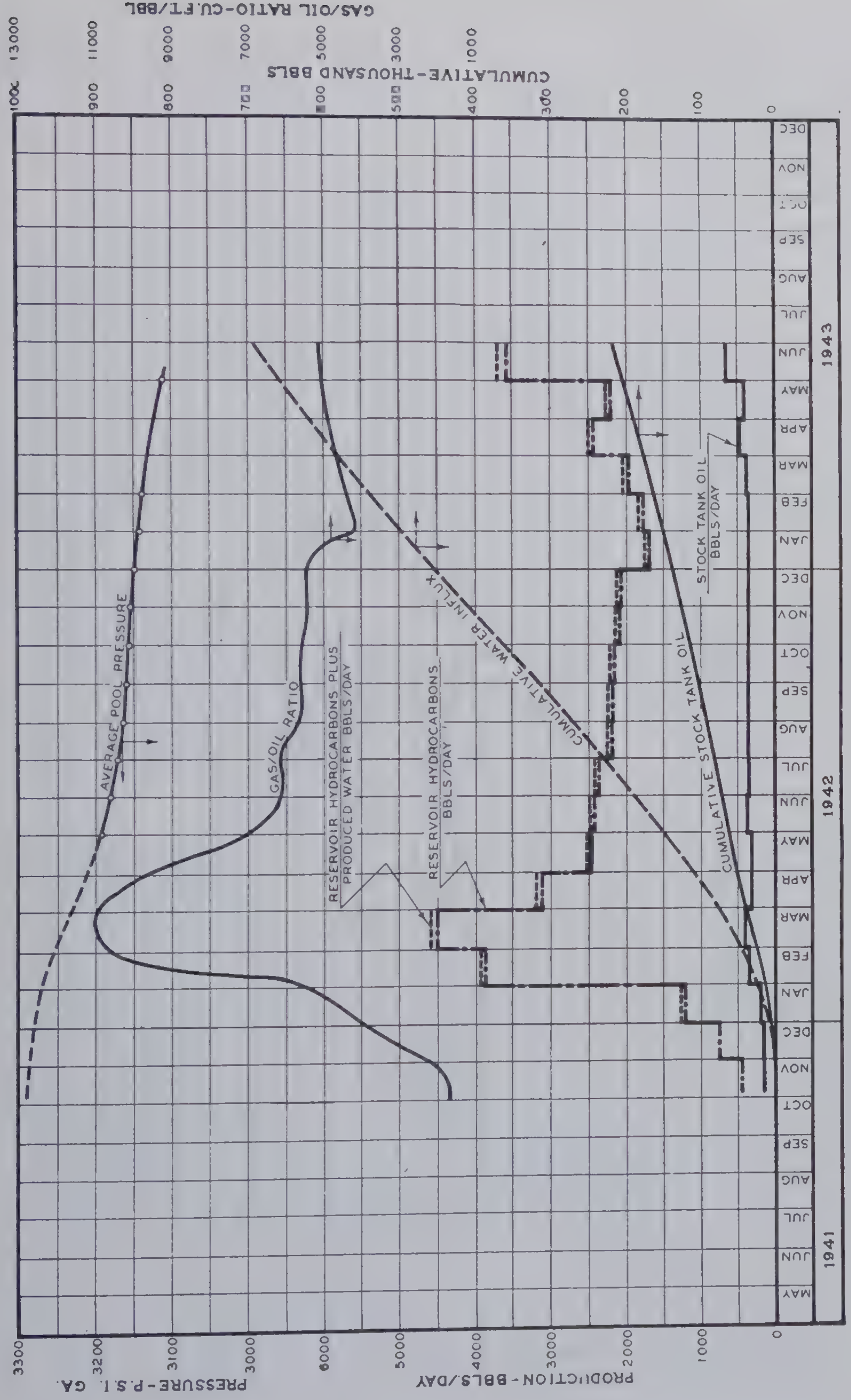

Fig. 9.—Mt. Holly production and pressure data.

lie in a symmetrical anticline, which is separated from the rest of the general Schuler anticlinal structure by a saddle that dips below the water-oil contact.

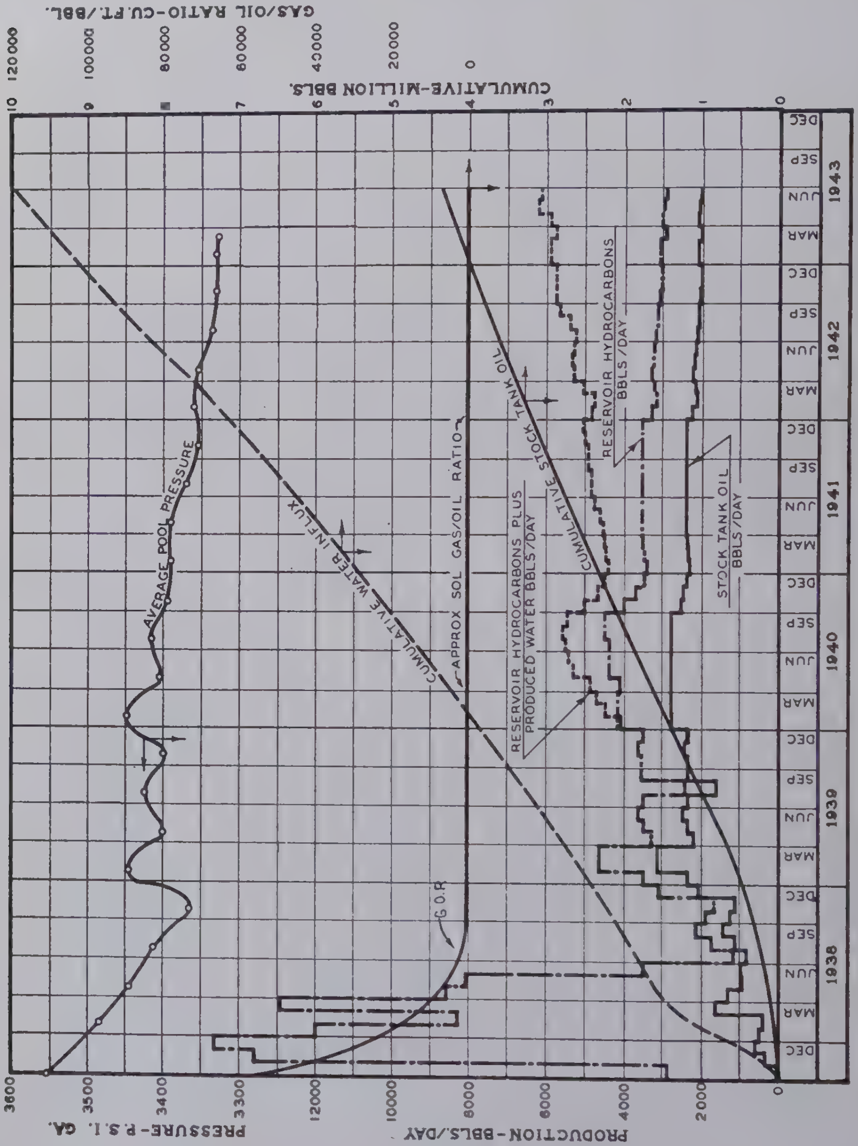

FIG. 10.—SCHULER PRODUCTION AND PRESSURE DATA.

The dominant feature of the Schuler (Reynolds) pool is its water drive. To date the water influx has amounted to more than nine million barrels. Water influx and other data are shown in Fig. 10. It has sustained the pool pressure 225 lb. below the original pressure. Analysis shows that unless other interfering pools are discovered very near to the Schuler pool, it will have sufficient water influx to produce all of the oil by a natural water drive. The future requirement for this

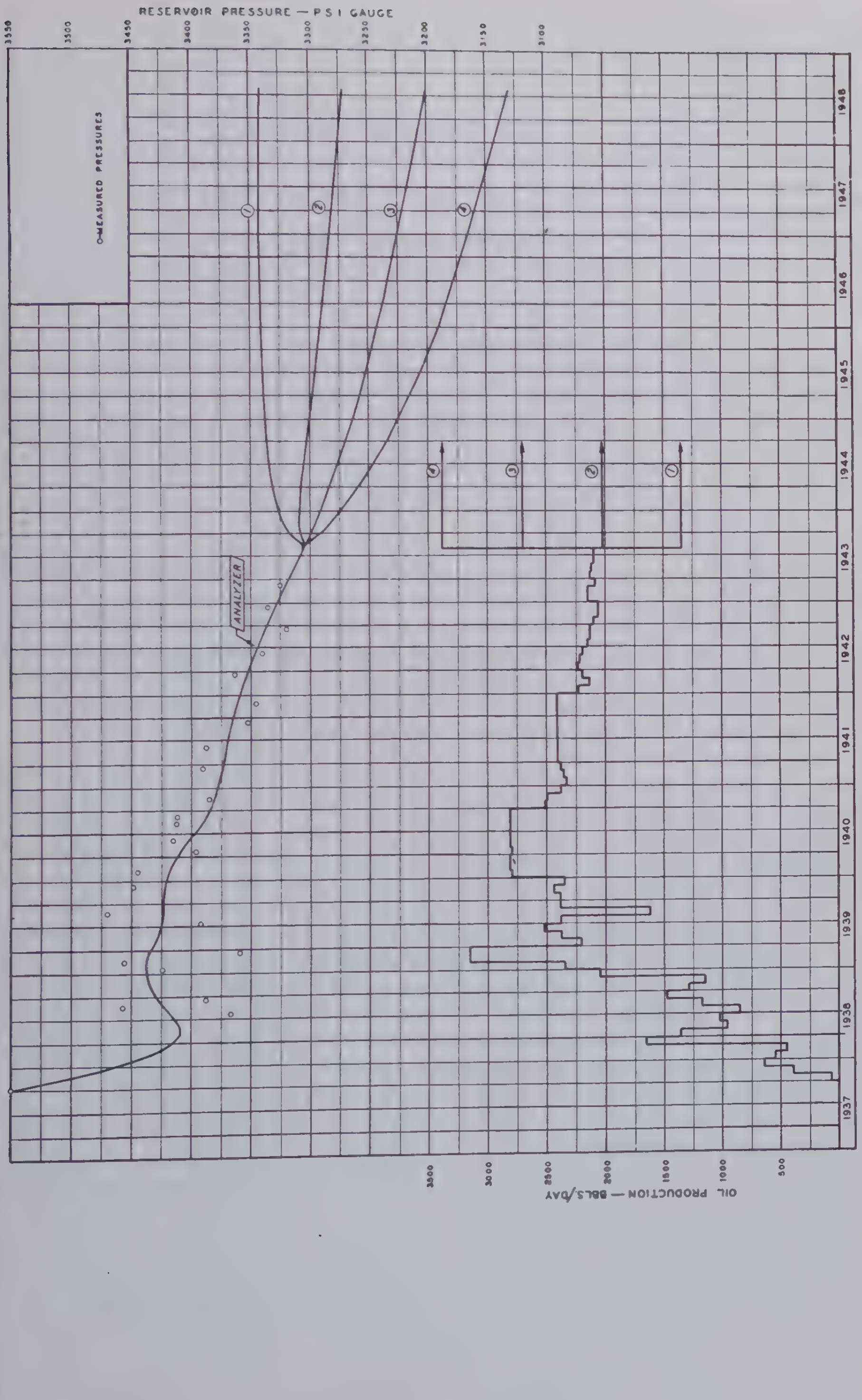

FIG. 11.—SCHULER (REYNOLDS) PRESSURE PREDICTION WITH FOUR PRODUCTION RATES AS INDICATED. NO CHANGE IN WATER ASSUMED.

will be 20 to 40 million barrels, depending upon the permitted water production.

Dry holes to the east, southeast, and south have shown porosity, permeability, and salt water. Pools and dry holes to the northwest and west indicate that Schuler is entirely surrounded by a porous, permeable, salt-water-filled aquifer.

The Justiss No. 3 shows porous, permeable, oölitic limestone to a depth of minus 7500 ft., or 80 ft. below the oil-water contact. Some porosity is found for 100 ft. below this, and 500 ft. below the top of the structure the well was drilling in dense, tight lime with dark argillaceous bands. No porosity whatever seems to have been found below 260 ft. from the top of the structure.

In analyzing the behavior of this pool, it was necessary to make more assumptions concerning the limits of the formation than in any of the pools so far discussed. However, as far as the pressure behavior is concerned, the predictions for this pool probably will be comparable in accuracy to the other predictions because of the small pressure drop to be anticipated in the development of this pool. Pressure predictions for various assumed conditions are shown in Fig. 11.

Since one fourth of the original gas cap was withdrawn in the first few months, leaving the gas cap less than one tenth of the total reservoir, and since the water drive has demonstrated its large capacity, it seems unlikely that there would be any possible economic advantage from attempting to prevent further shrinkage of the gas cap. This shrinkage will begin as soon as the gas-oil ratios become appreciably higher than their current values.

In comparison of the losses at this pool with those at Mt. Holly, it may be noted that with 65 per cent flushing efficiency the reservoir recovery factor would be 55 per cent, whereas with 80 per cent flushing efficiency the recovery factor would be 72 per cent.

As at Village and Mt. Holly, the current withdrawal rate at this pool is high. Based upon an estimated ultimate recoverable of 13 million barrels, one third of the original reserves has been obtained, and the current rate is 6 per cent per year.

Buckner Pool

The Buckner pool is an asymmetrical anticlinal fold lying almost against the regional fault zone. There is a dip to the east of the pool which has poor permeability and porosity and which led to the early definition between East Buckner and West Buckner. The larger part of the pool is west of the dip. The Buckner pool has been producing almost six years and has produced more than four million barrels of oil. Water influx is shown in Fig. 12.

The pool has a water drive which, although being limited in its power, has been able to hold the pool pressure to a reduction of 650 lb. The continuation of the water drive and its power to sustain the pressures above saturation pressure depend upon the source of the water.

It is believed that no fluid migration can take place across the regional fault zone because of the nature of the Reynolds zone near the fault, even though at some points the throw of the fault might not separate entirely the porous zones. Therefore, for the purpose of analyzing the Buckner problem, it is assumed that the fault zone represents a barrier to fluid flow.

Six miles northeast of the Buckner pool, a dry hole was drilled, which found 88 ft. of relatively poor porosity and permeability. Seven miles southeast of the pool is Big Creek and a dry hole. The latter well found 64 ft. of 14 per cent porosity and 5 to 10 md. permeability. Nine miles southwest are the McKamie and Patton pools, which show about 200 ft. of medium permeability and porosity. Five miles west is a well in the Lewisville pool showing over 50 ft. of highly porous but practically impermeable rock.

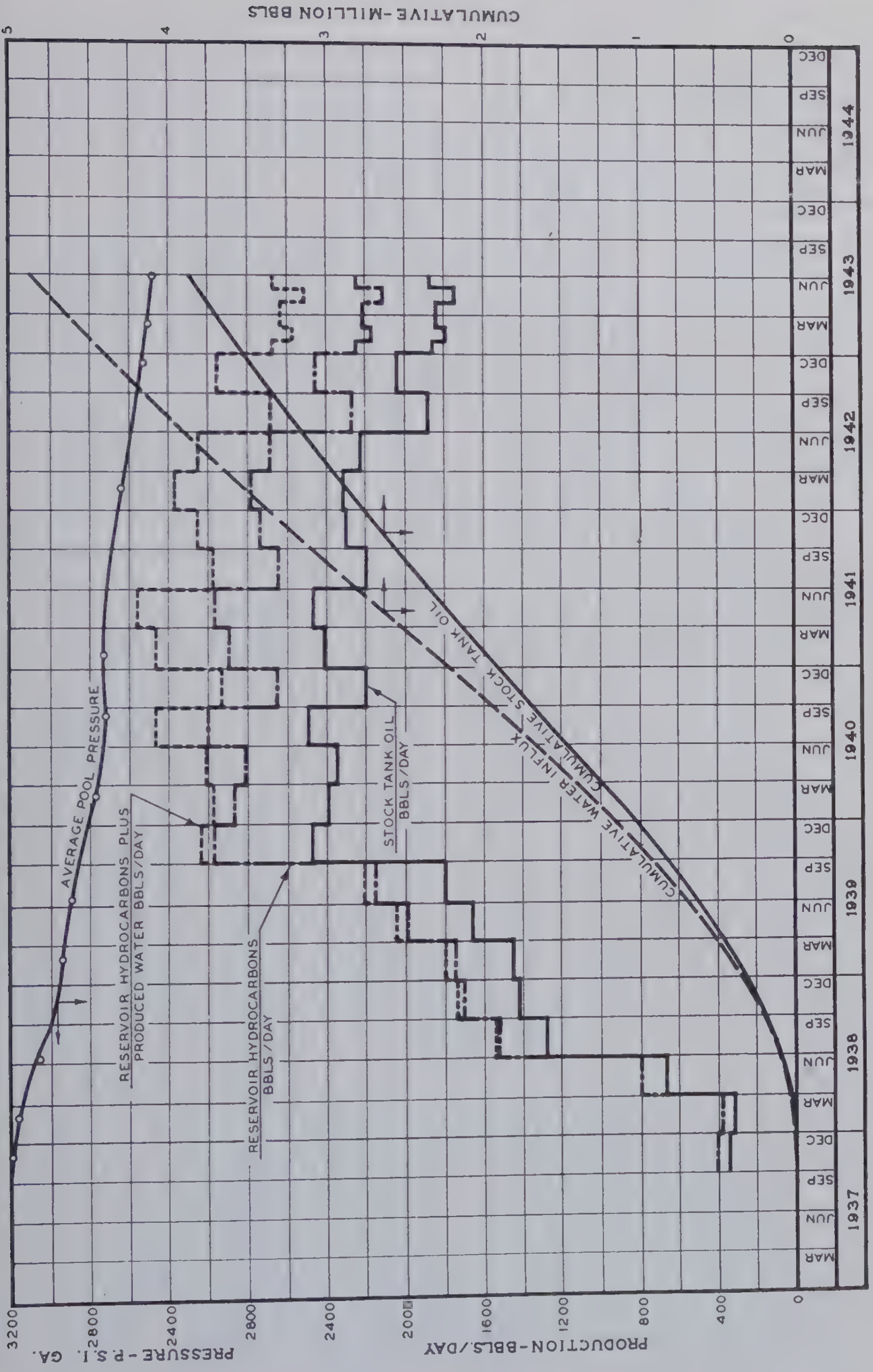

Fig. 12.—Buckner Production and Pressure Data.

An analysis of the Buckner problem shows that the over-all average permeability near the pool must be about 50 md., but this is indicated as diminishing to one half at 5 miles from the pool and as continually decreasing further away from the pool. Evidence from wells drilled to the south and west indicate that permeability should be getting better in these directions if some unknown factors are not involved.

The indication of an over-all diminution of permeability with distance from the pool, together with the fact that Buckner does not show any appreciable amount of hydrogen sulphide whereas all other Reynolds pools south of the fault zone do, make it seem possible that the Buckner pool may be partially isolated. If this pool is totally or partially isolated, its behavior in the future will be considerably different from predictions based upon the observed assumptions. Isolation of the pool would mean a more rapid pressure decline in the future than predicted. Predictions shown in Fig. 13 are based upon over-all homogeneous porous-media conditions. The effect of water injection as an aid to sustaining pressure is also shown in this figure. These pressure predictions and a more complete discussion of this problem was first presented in a special unpublished report by Bruce M. Bradley.

In this study of Buckner it has been assumed that all of the oil zone is connected. Hence, the figure of 43.3 million barrels of oil in place computed for the total pool was the figure used in all material-balance calculations for water influx. Actually it has not been demonstrated that oil can be moved out of a large part of the pool, which has high porosity but almost vanishing permeability. If a slowly rising water table is free to move up uniformly at Buckner, more than 20 million barrels of oil may be recovered from this pool. If, however, water moves horizontally along the upper, more permeable streaks, less than half this amount will be realized. Contemplated tests should tell in a few years which of these two widely different recoveries can be anticipated. In any event, it seems necessary to produce this pool very slowly for a maximum recovery.

Midway Pool

The Midway pool is the only major petroleum accumulation discovered north of the regional fault zone in the Smackover lime. It is an elongated anticline 4½ miles long by 1 mile wide, with a closure of more than 200 ft. The original reservoir pressure was 2920 lb., and the saturation pressure of the reservoir oil was 2528.

This pool has been in production for 1½ years, during which time about 2 million barrels of oil has been recovered and 2 million barrels of water has moved into the pool.

The movement of water into this pool to date has indicated the presence of a reasonably powerful water drive. Fig. 14 shows the calculated water influx. In regard to the future power of this water drive, it should be noted that the pool is bounded on all sides by barriers. The original fault line is 3½ miles to the southeast. The northern limit of the Smackover formation is 10 miles to the north, and dry holes drilled 6, 10, 18, and 23 miles to the west indicate a gradual but definite thinning of the porous zone. One dry hole 18 miles west of Midway has less than 34 ft. of very poor porosity. Incomplete evidence indicates that the porous zone is also thinning to the northeast.

As far as these factors are known, they have been taken into account in an analysis of the behavior of Midway and in a prediction of future pressures. This pressure prediction is shown in Fig. 15.

The operators[10] of this pool have started a program of water injection (see Fig. 14 for rates) and from the early success of this program it is anticipated that water injection will be continued into the future. The

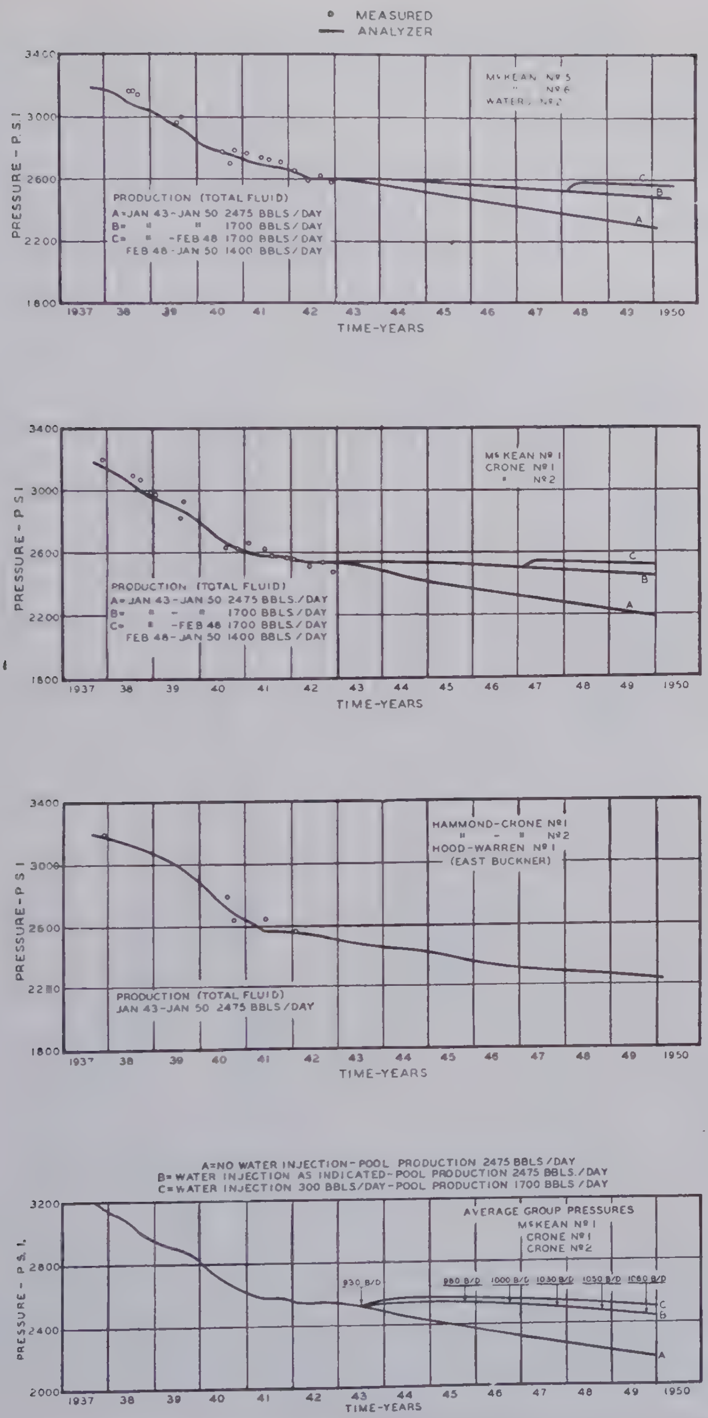

FIG. 13.—PREDICTED AND OBSERVED PRESSURES FOR THREE WELL GROUPS AT BUCKNER
The bottom graph shows the expected effect of injection.

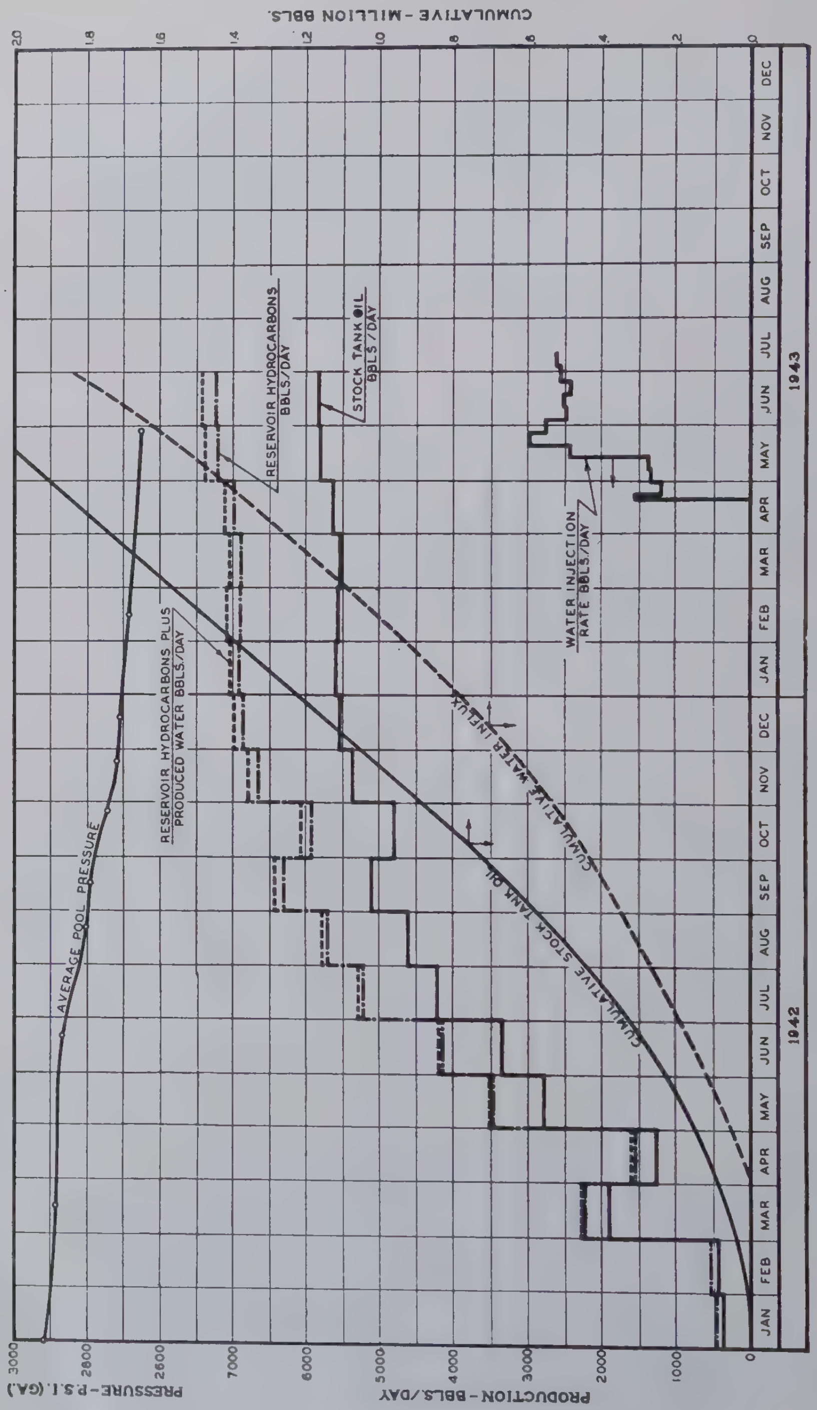

FIG. 14.—MIDWAY PRODUCTION AND PRESSURE DATA.

effects of various possibilities under consideration are shown in the pressure predictions of Fig. 15.

The injection of water has been made in an abandoned dry hole, which was deepened to the base of the porosity. The injection well was cased 100 ft. below the water-oil contact, to avoid the possibility of water channeling. This enterprise is to be distinguished from a water flood. The operators hope to add water to the prevailing natural water drive and to use that water to sustain pressures rather than to drive the oil horizontally to the producing wells. If this project is successful, water will rise in a rough horizontal plane. Early effects of the injection on distant wells will be a mark of success.

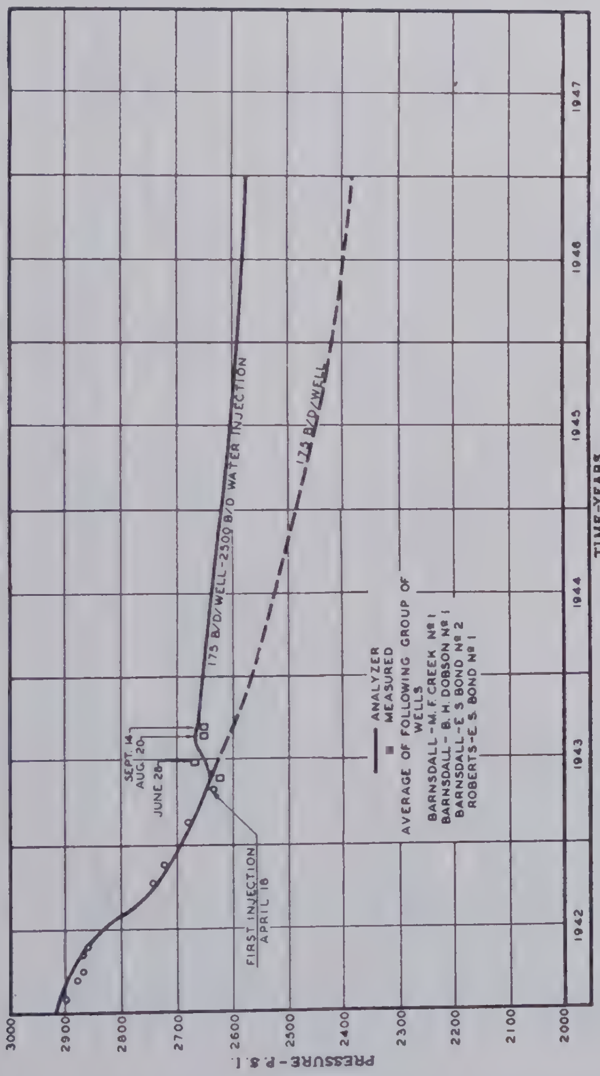

FIG. 15*a*.

FIG. 15.—PRESSURE PREDICTIONS AT MIDWAY MADE JUST BEFORE INJECTION.
Squares represent measured pressures after the prediction.

The effect of this water injection is twofold. It will sustain pressures, thereby prolonging the flowing life of the wells, and it will prevent the gas from coming out of solution by holding the reservoir pressure above the saturation point. In the analysis of this problem considerable modification of the analyzer was necessary although the fundamental principles previously described[7] were followed.

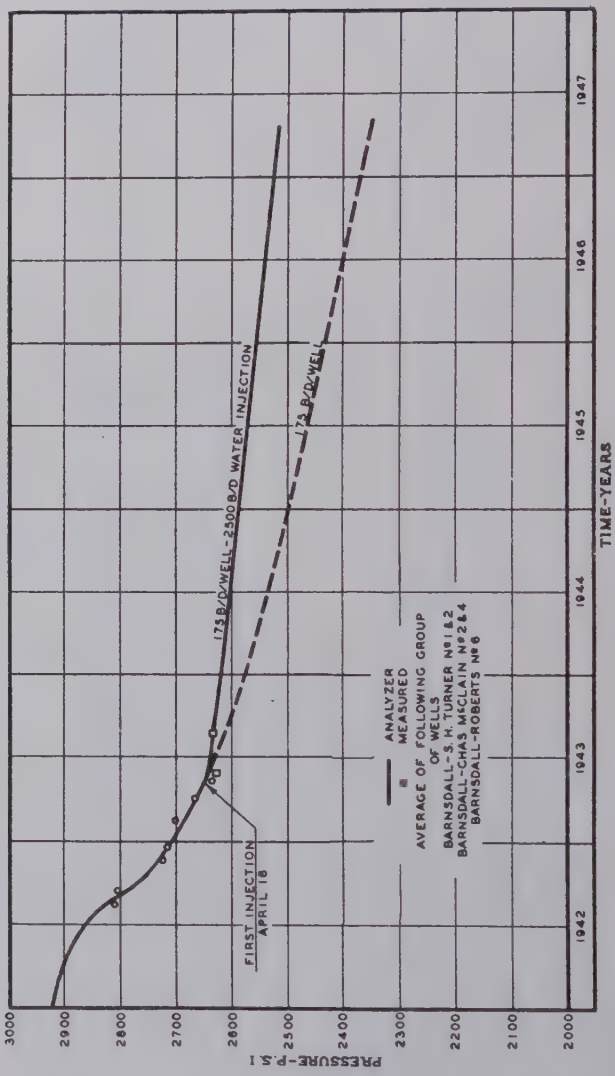

FIG. 15*b*.

Core-analysis information indicates that at least 50 per cent flushing action may be anticipated in this pool. If no water injection were made at this pool and normal water production could be assumed, more than 100 million barrels of water would have to invade the pool in order to produce all of the oil anticipated as a possible maximum recovery.

It is doubtful whether so much water would be available by the expansion of the water now known to be in this part of the Smackover formation. On the other hand, if the injection program continues as planned, the requirement of water influx will be less than one tenth of this amount and the limitations of the water reservoir will be relatively unimportant as far as the future behavior of Midway is concerned.

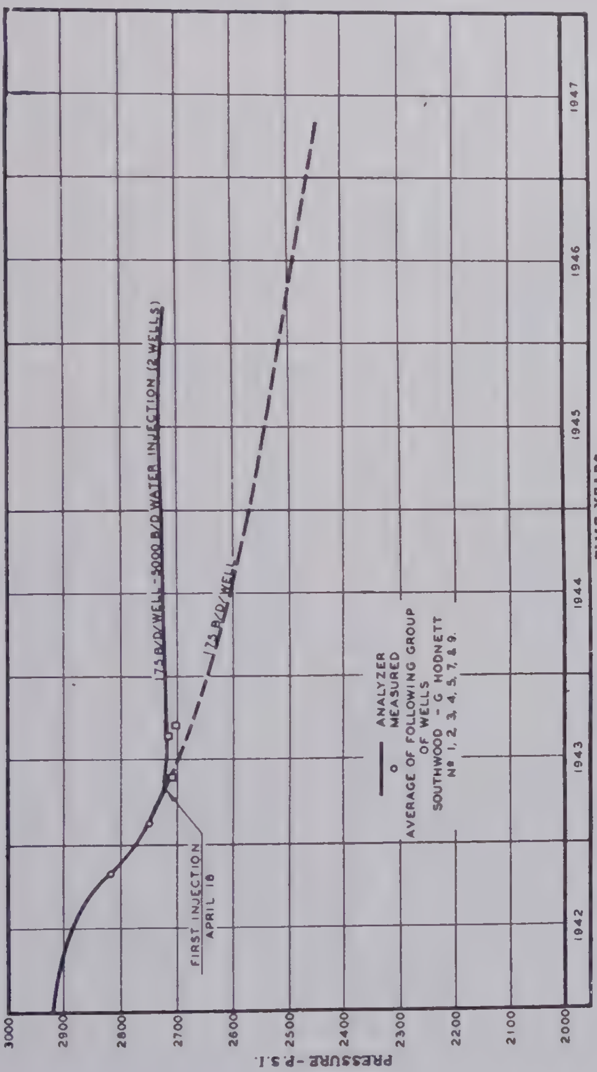

FIG. 15C.

McKAMIE POOL

The McKamie pool is a gas-distillate accumulation in an anticlinal structure of the Reynolds lime. Its structural condition is complicated by two faults, neither of which has been completely defined. It is possible that both of these faults are localized to the area of the uplifted anticline. The effect that they have had so far upon the influx of water into this pool has been to diminish the rate of influx to one half that which would normally have been expected in this part of the Smackover limestone (Tables 1, 2, and 3). The effect of these faults on the future behavior of the pool can only be roughly estimated at this time. To date it is estimated that 4 million barrels of water have moved into this pool. This has been accompanied by a pressure decline of 270 pounds.

Direct evidence that this pool has a water drive has been the rise in pressure from an average of 4140 to 4170 in the four months that it has been shut down (pending the construction of a desulphurization plant). For a complete picture of the pool's behavior see Fig. 16.

The behavior of this pool to date indicates that a production rate of 2000 bbl. of distillate and 16 million cubic feet of gas can be continued for the next 10 years with an end pressure of 3700 lb. Thus, it may be seen that while the water drive at this pool is not sufficient to sustain the pressure and prevent any loss from reservoir condensation, it will aid in retarding the pressure decline. It is estimated that without water drive the decline in pressure would be almost double that estimated on the assumption of the water drive so far indicated. The effect of the faults on this prediction will make the prediction on the low side if the faults are not extensive and on the high side if other faults not considered are present. The recent pressure build-up makes the presence of other extensive faults unlikely.

The smallness of this pressure build-up is due to the large gas cap and its cushioning effect. On the basis of the geologically determined gas in place, a pressure build-up of one pound in the range 4140 to 4170 represents the influx of 40,000 bbl. of water. Hence, 30 lb. per sq. in. indicates 1,200,000 bbl. in four months, although the amount of gas being taken from the pool in this interval was negligible.

ATLANTA POOL

The Atlanta pool has not been analyzed with the care and detail devoted to the first seven pools discussed. The gas data in the early days were open to question, hence it is desirable to wait until these early inaccuracies have a less important bearing upon current behavior.

The limited study made on the Atlanta problem indicates that the pool has a good water drive. Table 3 shows the effective permeability and water-compressibility data. As to future water available, the nature of the Smackover south of the pool is not well enough known to make a prediction beyond 10 years, but at the present rates it seems that this pool will be largely depleted in another 10 years, in which case the question of available water supply may be relatively unimportant.

BIG CREEK AND TEXARKANA POOLS

Two one-well distillate pools, Big Creek and Texarkana, are included in this report only to indicate that each has good water drive even though the porous-media conditions are poor. For every barrel of distillate produced, about 25 bbl. of reservoir gas must be withdrawn; hence 200 bbl. per day means 5000 subsurface barrels. This is only partly offset by the expansion of gas in place. The current rate of water influx at Big Creek is estimated to be 2500 and at Texarkana is 1500 bbl. per day.

Factual data for the pools are shown in Tables 1 and 2. Obviously the data on volume and area are questionable, even for Big Creek, where two dry holes flanked the producer and thereby indicated the shape of the structure. These inaccuracies should not affect the water-influx data

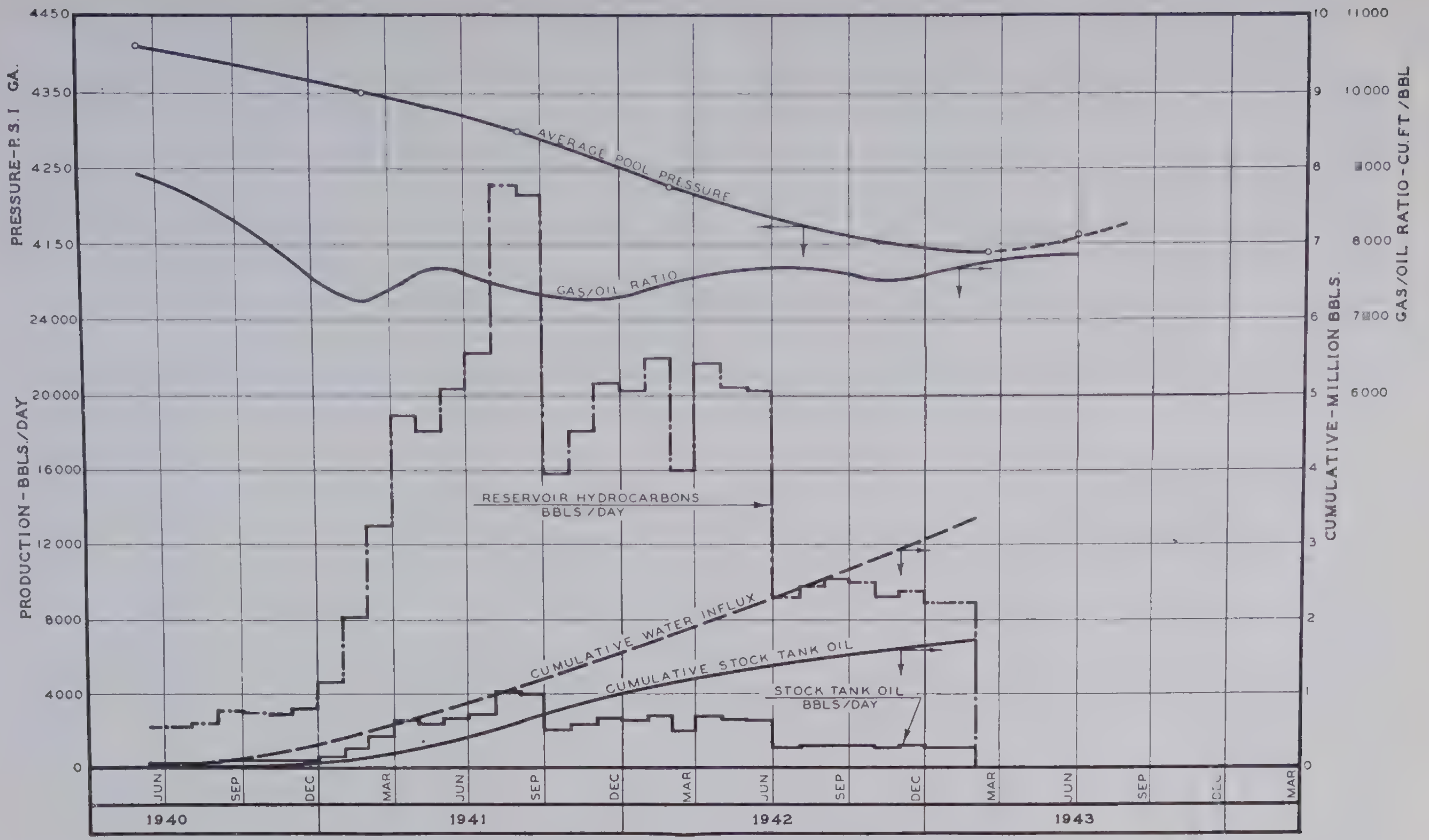

FIG. 16.—McKAMIE PRODUCTION AND PRESSURE DATA.

more than 20 per cent. Water influx has been 2½ million barrels at Big Creek and ½ million barrels at Texarkana.

Dorcheat and Macedonia Pools

The Dorcheat and Macedonia pools originally were thought of as two separate pools. Dorcheat was discovered Aug. 28, 1939. The discovery well encountered good oil-filled porosity, and was perforated from minus 8641 to minus 8655. The well flowed 43.5° gravity oil and 1000 cu. ft. of gas per barrel, indicating that the oil zone was probably very thin. Dorcheat has produced nearly 2 million barrels of oil and 18 billion cubic feet of gas. During this time there has been a drop in pressure of 930 pounds.

Macedonia, which was developed some two years later than Dorcheat, has produced 600,000 bbl. of oil and 7 billion cubic feet of gas. The pressure drop has been 430 pounds.

Thus, for a matter of 3 years the pressure differential from Macedonia to Dorcheat has been between 400 and 500 lb., and it seems almost certain that oil has moved from the Macedonia into the Dorcheat pool. This is indicated in the calculations of water influx. Considering the pools as separate, water influx for Dorcheat has been 2.3 million barrels. For Macedonia, the calculated "water influx" has been negative. If this calculation can be trusted, it means that more fluid has moved out of the pool—and presumably migrated into the Dorcheat area—than water has been able to enter the pool area. This last conclusion is open to a certain amount of question, owing to inaccurate and inadequate gas-production data. One indication of the possible inaccuracies of these data is the negative water influx indicated for Dorcheat during its first year's production, although the total is now positive.

Regardless of these inaccuracies, water is moving into these two pools, considered as a unit, and in the future the amounts will be determinable.

Direct evidence of the water movement has been the rise in pressure observed in both areas after the pool was shut down pending a market for the gas. Between March 5 and April 8 the average pressure of both zones rose 100 pounds.

Analysis of the Dorcheat behavior alone indicates a lower effective permeability than for any other Smackover pool so far studied.

Water-drive Efficiency

Now that the presence of water drive has been established for each of the pools in this formation, the next question is the efficiency with which the inflowing water is displacing oil. The first assumption that will be made concerning water-drive efficiency is that the general movement of water will be vertical. A good basis for this assumption lies in the high vertical permeability found in most places, but even in spots that have barriers to direct vertical flow the general motion of water will have a vertical component due to the structural conditions. Therefore, if the motion of water is slow, and in most places it is likely not to exceed 5 vertical feet per year, the forces of gravity can be relied upon to maintain a roughly plane horizontal water table.

From this assumption as a base, three lines of approach will be used to give an indication of the water-drive efficiency:

First, it will be noted that laboratory experiments dealing with sands and with fragments of cores taken from very porous parts of the Smackover formation have shown that water moving up slowly through the porous medium can be expected to displace as much as 95 per cent of the original oil in place. The commonest condition is a displacement of oil corresponding to 80 per cent of the pore volume. In some cases of poor permeability, displacements as low as 50 per cent have been observed.

Thus, a range of 50 to 95 per cent, with a most likely value of 80 per cent, has been indicated for the highly permeable, porous media used in laboratory experiments under ideal conditions.

Second, residual fluids in cores can be used to infer what was in place in the reservoir and how much was removed in the coring operation. A core properly handled and brought into the laboratory has oil, connate water, and drilling water in it. These fluids are not in the same proportions as they were prior to the drilling operation. During the drilling and cutting of a core the drilling fluid forces some oil and water out of the core. The remainder is brought to the surface, but during the trip portions of both oil and water are expelled by the expansion of gas released from the oil. Laboratory and field experiments have demonstrated that the amount of oil expelled during this process is unlikely to exceed one third of the amount remaining and is proportionately less for smaller quantities of residual oil.

On the basis of this, it has been assumed that an indication of minimum flushing by water could be obtained by taking an average of the residual oil found in cores, adding to that one third, and correcting for shrinkage. On the basis of this assumption, the flushing efficiency of Buckner would be 56 per cent, at Village 78 per cent, at Schuler 75 per cent, and at Magnolia 69 per cent. These first two methods fail to account for the loss of oil caused by trapping against some closed vertical barrier or oil by-passed and left locked in zones already flooded.

A third method of estimating flooding efficiency is based upon the observed water produced in wells. This can be used successfully only where the sand is fairly homogeneous and highly permeable, because without homogeneity the apparent position of the water-oil contact depends to a great extent upon local anomalies. The use of this method also demands accurate knowledge of the original oil in place and of the original water-oil contact. Application of this method to the Village and Schuler reservoirs has been made as follows: Fig. 17 shows the original position of the water-oil contact for these pools and its estimated location in January 1943. Information on the Village pool seems to be the more accurate of the two studied, and this indicates between 58 and 82 per cent oil flush from the porous, oil-filled lime invaded by water. The Schuler data indicate over 50 per cent flushing efficiency.

All known factors governing the behavior of oil and water in porous media indicate that the average flushing efficiency at these two pools should be as high, if not higher, than that anticipated for any of the other pools, so that the minimum of 58 per cent at Village should not be taken as proof that at least 58 per cent efficiency is to be expected in all of the Smackover pools.

It should be remembered that this discussion pertains to the flushing efficiency of water for oil in a zone through which the water is passed, and does not refer to the over-all pool-recovery factor, which must always be lower than the efficiency of a particular section considered.

COMPARISONS

Table 3 contains the results of the analysis of each water drive. The procedure was to adjust the analyzer[7] until it reproduced the pressure history of the pool. The values of resistors and capacitors necessary for accurate reproduction, together with the factors L, M, and N necessary for conversion from reservoir to electrical units, determined two physical quantities: (1) the transmissibility factor kb/v (permeability times thickness divided by viscosity), and (2) the storage capacity (effective compressibility times porosity times thickness—in the table, the estimated porosity was divided out). These values were arbitrarily determined for a zone about 5 miles from the pool considered.

These results show some variation but nothing like the variation of the porous media in individual pools. None of the transmissibility factors are more than double or much less than half the average, whereas in Table 1 it may be observed that permeabilities within the pools vary as much as thirty-fold.

A larger variation among the storage factors will be noted. This reflects in part the insensitive nature of this determination by analysis; also, in part it reflects lack of geological information about location of minor faults, the possibility of impermeable synclincal areas, and so forth.

In regard to the average transmissibility factor, it will immediately be observed that the average permeability is lower than that indicated inside any pool. Based on 100 ft. of porous formation, the average permeability is 30 md. and the highest is less than 60 md. This may be interpreted to mean that the Reynolds lime is effectively less permeable in the areas between pools than in or very near any pool. While this hypothesis is not unique, it is strongly indicated by these analyses because all other hypotheses tested failed to give reproductions of the observed behaviors. From a geological point of view, this reduction in permeability is not unreasonable, since, aside from possible barriers created by diastrophism, there is the indication that secondary processes contributed to higher permeabilities in the higher parts of the formation. It is not an unreasonable hypothesis that final lithification left synclinal areas almost totally impermeable.

The average storage factor shown below Table 3 indicates an effective compressibility about twice that of water as measured in the laboratory.

It is believed that a comparison of the size and shape of these pools with the apparent transmissibility as determined by analysis may illustrate some of the fundamental principles of water drives. Note that kb/v for Magnolia is about the same or a little higher than for Schuler, and yet note that the apparent water drive at Schuler is much better than at Magnolia. The explanation for this is a part of the fundamentals of compressible liquid behavior in a porous media; namely, in a given homogeneous aquifer, the smaller the pool, the more powerful the water drive, if the withdrawal rates are based on acreage or reservoir volume.

Another principle illustrated by the data is that a large pool very near a small one may have a greater influence on the pressure behavior of the smaller one than the production at the smaller one does on itself and, if this effect becomes appreciable in one or two years, it will become progressively greater with time.

Acknowledgments

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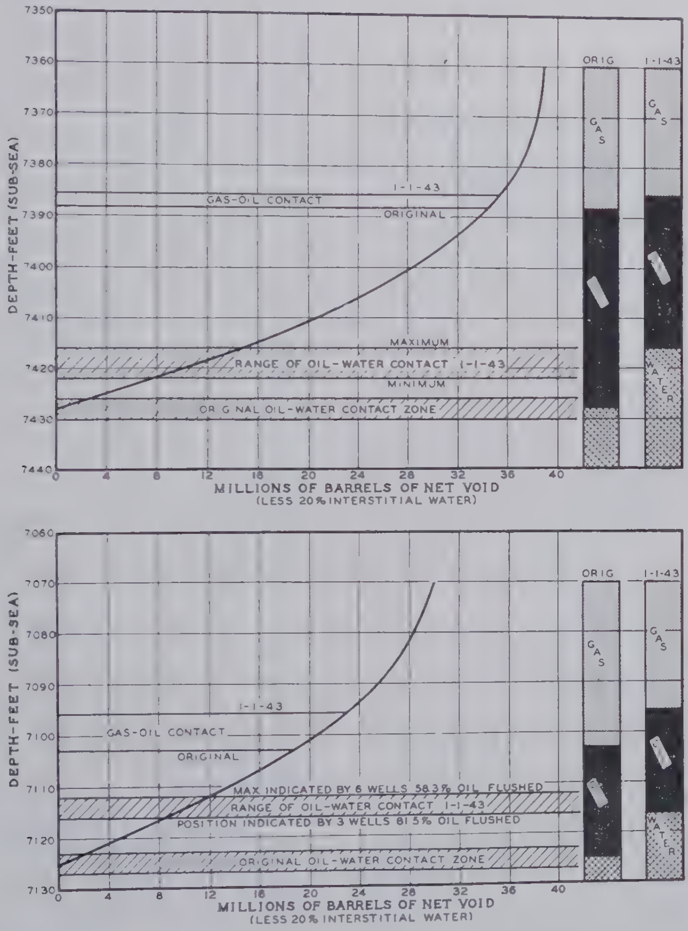

FIG. 17.—STUDY OF FLUSHING EFFICIENCY BY MEASUREMENTS OF WATER-TABLE RISE.

Prediction of Reservoir Behavior from Laboratory Data

By E. C. Babson,* Member A.I.M.E.

(Los Angeles Meeting, October 1942)

Abstract

In order to explore the possibility of predicting reservoir performance from laboratory data, behavior of a hypothetical low-permeability reservoir has been estimated by applying data and methods currently available in the literature. A method of calculating decline in productivity index is discussed, and recoveries by internal gas drive, external gas drive and water drive are estimated.

Introduction

During the life of a producing oil property an operator is faced with many perplexing problems. Any attempt to determine proper well spacing, optimum rate of production, or the desirability of pressure maintenance requires the evaluation not only of a host of economic and practical operating factors but also of the future performance of the reservoir. Although in some cases economic or operating considerations may be of primary importance in planning a development or production program, the anticipated effect on ultimate recovery is more likely to be the decisive factor.

The soundest basis for evaluating reservoir performance is past experience with oil fields, but pertinent data are difficult to obtain or apply under conditions normally encountered in California fields. Many of these fields are characterized by thick sections of alternating sands and shales complicated by faulting and rapidly changing lithologic conditions. Further complications are introduced by haphazard development and production practices resulting from competitive conditions, changing demand for oil, and insufficient knowledge of structural conditions during early development. Even in the rare cases where development has been systematic and adequate, production policy has usually been controlled by economic and competitive factors rather than a desire to obtain information for use in future operations. In other words, comparable reservoirs in which development and production practices have been systematically varied are seldom found.

In the light of these conditions, conclusions based on experiences usually lack the certainty required for decisions involving large sums of money. Some other method of attacking these problems is needed to supplement and orient field experience. Progress in laboratory investigations of the flow of oil, gas, and water through sands has been so rapid in recent years that these data may furnish such a supplementary approach in the near future. In order to explore this possibility the author has attempted to predict the behavior of one type of reservoir by applying published data and methods.

Basic Data and Assumptions

Calculations outlined in this paper are dependent upon a detailed knowledge of the properties of oil, gas, and water present in the reservoir and the portion of the total pore space originally filled by each. It is also necessary to know how the permeability of the sand to oil, gas, and water varies with the saturations of these fluids

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in the sand. Furthermore, it has been necessary to make certain simplifying assumptions in order to perform the calculations within a reasonable period of time. In making assumptions and choosing data, the writer has attempted to duplicate as nearly as possible conditions encountered in certain California oil fields.

The hypothetical reservoir used in the calculations was assumed to have a porosity of 21 per cent, of which 25 per cent was originally filled with water and 75 per cent with oil containing 700 cu. ft. of dissolved gas per barrel of tank oil. Reservoir temperature was 210° and original pressure was 3000 lb. per sq. in. abs. Properties of the oil and gas were assumed to be similar to those of Dominguez oil and gas described by Sage and Lacey.[1,2] Volumetric data for both oil and gas and viscosity data for the oil phase were taken from these papers. Viscosity data for a "lean natural gas" given by Sage and Lacey in another paper[3] were used for the gas phase in the present investigation. These phase data indicate that the bubble point of the original reservoir contents was 3000 lb. per sq. in. abs. and that the initial formation volume factor was 1.42. It was assumed that the oil and gas in the reservoir maintained phase equilibrium at all times. This assumption may not be strictly true, but calculations are almost impossible without it.

Sand permeability was assumed to be too low to permit appreciable recovery of oil by gravity drainage. Despite this assumption, it was necessary to use the data of Leverett and Lewis[4] on the relation between the relative permeabilities to oil, gas, and water and the saturation of these fluids. Their data seem inappropriate because an unconsolidated sand of very high permeability was used in their experiments, but no other data on the flow of all three phases through sands have been published. Botset[5] obtained data on the flow of mixtures of carbon dioxide and water through a consolidated sand of moderate permeability. An attempt was made to adjust his data for the presence of a third phase, but the basis for this adjustment was not too satisfactory. Furthermore, the data of Krutter[6] on the flow of gas through oil-saturated consolidated sands seem to agree more closely with Leverett and Lewis than with Botset.

Because these data of Leverett and Lewis form the keystone of this entire paper, a brief review of their conclusions seems appropriate. They concluded that a sand could be considered to have simultaneously an effective permeability to oil, an effective permeability to gas, and an effective permeability to water, and that variables other than the oil, gas, and water saturations affected these permeabilities only to a very minor degree. (In this paper the terms "oil saturation," "gas saturation," and "water saturation" mean the percentage of the total pore space occupied by the corresponding phase in the reservoir.) Effective permeabilities were expressed not in millidarcys but as percentages relative to the permeability of the sand to air. The relative permeability to each phase was 100 per cent at 100 per cent saturation of that phase and decreased as the saturation decreased.

As oil is produced from a sand, the oil saturation decreases and the space thus voided becomes filled with either gas or water, or both. Thus the permeability of the sand to oil decreases and the permeability to gas or water increases. In oil fields we see the effects of these changes in declining productivity indices and rising gas-oil ratios and cuts. The data of Leverett and Lewis furnish a means by which productivity index, gas-oil ratio, and water cut can be related to stage of depletion.

DECLINE IN PRODUCTIVITY INDEX

One source of great concern to the production engineer is the decline in productivity

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[1] References are at the end of the paper.

index usually observed in depletion-type fields. Various explanations have been offered to explain this decline—transportation of silt, precipitation of asphaltenes, accumulation of water near the well bore, and plugging of perforations in the liner. While all these factors may contribute to the decline, published data on the relation between permeability to oil and oil saturation indicate that the productivity index must decline as the oil in the neighborhood of a well is depleted. Since low productivity indices can result in early abandonment of wells, it is important to know what causes the observed decline and what can be done about it. In order to throw some light on this problem, an attempt has been made to determine how the productivity index should vary with pressure and gas-oil ratio for the assumed reservoir conditions. By checking this theoretical decline against actual declines observed in wells producing from similar reservoirs, it may be possible to determine whether the observed decline can be accounted for by depletion alone or whether some other cause must be found.

A method described by Evinger and Muskat[7] has been used in making the calculations. This method assumes that flow through sand is steady with respect to both mass and composition of the flowing stream. Since the present calculations are for the purpose of estimating the change in productivity index rather than its absolute magnitude, the equation of Evinger and Muskat has been modified to give a relative productivity index.

$$I/I_1 = \frac{1}{P_e - P_w}\left(\frac{\mu_o\beta}{K_o/K}\right)_1 \int_{P_w}^{P_e} \frac{K_o/K}{\mu_o\beta}\, dP \quad [1]^*$$

In which I_1 is the productivity index under some standard reservoir conditions and at a pressure differential approaching zero. (In this paper the term "pressure differential" refers to the difference between the static and producing pressures in a well, and this difference is considered to be equivalent to the term $(P_e - P_w)$ in Eq. 1). Since the choice of standard conditions is purely a matter of convenience, initial conditions in the assumed reservoir were taken as standard. When the corresponding permeabilities and viscosities are substituted in Eq. 1, the following equation results:

$$I/I_1 = \frac{12.2}{P_e - P_w} \int_{P_w}^{P_e} \frac{K_o/K}{\mu_o\beta}\, dP \quad [2]$$

In order to solve this equation it is necessary to know how the relative permeability to oil K_o/K varies with pressure. This can be determined by utilizing another equation of Evinger and Muskat:

$$K_g/K_o = \frac{(R - M)\mu_g}{\rho\beta\mu_o} \quad [3$$

The variation of the ratio of effective permeabilities to gas and oil, K_g/K_o, with pressure can be established for any produced gas-oil ratio R by assuming different pressures and substituting appropriate values for the remaining factors. The relative permeability to oil K_o/K, corresponding to any value of K_g/K_o can be determined from the data of Leverett and Lewis if the water saturation is known. The expression following the integral sign in Eq. 2 can then be evaluated as a function of pressure, and the relative productivity index can be obtained by graphical integration.

Results of these calculations for a series of gas-oil ratios and pressures are shown in Fig. 1. The correct method of calculating a relative productivity index for a given gas-oil ratio is to determine the area under the appropriate curve between the static and producing pressures and divide this area by the pressure differential. Under most conditions, however, the curves in Fig. 1 are almost linear, and for moderate pressure differential the relative productivity index can be read directly from the chart by using a pressure midway between the static and the producing pressures.

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* See nomenclature on page 131.

These curves show what Evinger and Muskat have already stated—that the productivity index decreases as the pressure differential increases. At first thought, this seems contrary to field experience because indices of actual wells do not vary in any predictable manner with pressure differential. A possible cause of this discrepancy becomes apparent when the matter is given further consideration. Productivity index is a function of the average permeability of the sand to oil, which in turn is a function of the saturation distribution in the sand. If a well is produced at a pressure differential of 200 lb. per sq. in. for several weeks, the saturation distribution around the well will gradually adjust itself to this pressure gradient and a certain productivity index will be attained. If the well is then opened up to a differential of 1000 lb. per sq. in., the saturation distribution around the well will tend to change and the productivity index will tend to decrease. Since a large volume of oil must be moved in order to alter the saturation distribution, the process requires considerable time. If a test is made on the well a day or two after the production rate has been increased, it is probable that the saturation distribution will have changed only slightly and the productivity index will be practically the same as at the lower rate. Because of this

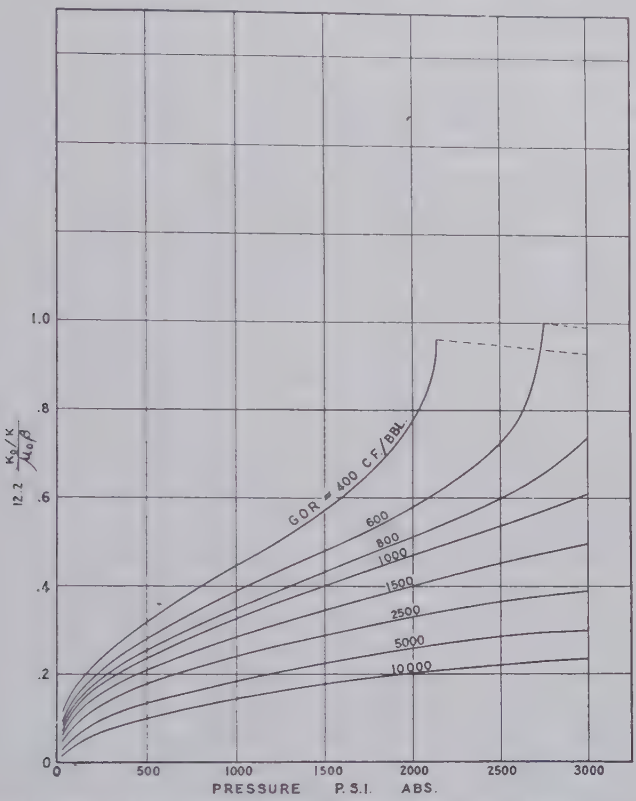

FIG. 1.—RELATION BETWEEN PRODUCTIVITY INDEX, GAS-OIL RATIO, AND PRESSURE AT 25 PER CENT WATER SATURATION.

behavior the pressures used in evaluating a productivity index by means of Fig. 1 should relate to the normal production rate of the well rather than conditions during a short-time test.

In order to illustrate how these results can be used in predicting the decline in productivity index, an illustrative example will be worked out. If a well has a productivity index of 1.5 when the gas-oil ratio is 1000 cu. ft. per barrel, the static pressure is 2500 lb. per sq. in. abs., and the producing pressure is 2300 lb. per sq. in. abs., what will the productivity index be at a gas-oil ratio of 2500 cu. ft. per barrel, a static pressure of 1500 lb. and a producing pressure of 1000 lb. per sq. in.? From Fig. 1, it can be determined that I/I_1 for the first set of conditions is 0.523, so I_1 is equal to 1.5/0.523, or 2.87. For the second set of conditions I/I_1 is 0.264 and the productivity index is 0.264×2.87, or 0.76. Preliminary application of this method to data on several wells in a depletion-type field of low permeability has shown that the productivity indices actually decline somewhat less than the calculations indicate. As far as the wells studied are concerned, depletion of the oil can tentatively be considered the principal cause of productivity-index decline.

Internal Gas Drive

In general, oil can be recovered from a sand by four methods: (1) internal gas drive, (2) external gas drive, (3) water drive, and (4) gravity drainage. Internal gas drive is the normal depletion process in which oil is displaced by originally dissolved gas. External gas drive is a process in which a gas front advances through the sand, displacing oil ahead of it. Water drive operates by a similar mechanism with water as the displacing fluid. In sands of high permeability large quantities of oil can be recovered by gravity drainage. In most reservoirs all four of these processes are operative in some degree, but usually only one or two of them are important from the standpoint of recovery.

In this paper gravity flow is considered to be an unimportant factor in production on account of the low permeability of the sand, and if natural water drive is ineffective, the operator is in a position to choose the method by which oil is recovered from the sand. If the operator simply produces oil from all his wells until they no longer yield a profit and then abandons them, the reservoir will have been depleted by internal gas drive. This method has been applied almost universally in the past, largely because of its simplicity.

Given the relation between oil saturation and the relative permeabilities to oil and gas, it is possible to calculate future trends of static pressure, productivity index, and gas-oil ratio for wells producing from a reservoir of this character by considering flow through the sand as a succession of steady states. If the wells are produced at appreciable pressure differentials the area around a well should be divided into rings and the flow between these rings investigated in detail in order properly to evaluate saturation gradients. It is entirely feasible by this method to calculate future trends of pressure and productivity for the entire producing life of a reservoir, but, unfortunately, the task is an extremely laborious one and has, therefore, not been attempted. This is regrettable, for such calculations might furnish information useful in determining optimum well spacing and optimum rate of production, providing that data pertinent to the actual sand in the reservoir could be used.

Since time was not available for the more detailed calculations, future trends for the hypothetical reservoir have been estimated by assuming that the oil is produced at negligible individual well-pressure differentials. It is realized that calculations for high-pressure differentials would probably indicate more rapidly rising gas-oil ratios together with a more rapid pressure decline, but it seems likely that the recovery calculated for the case of negligible pressure differential is an upper limit which would be approached at small but finite differentials. The method is illustrated by the sample calculation in Table 1. The method is a trial and error process in which small quantities of oil and gas are assumed to be withdrawn from the reservoir and the resultant pressure is estimated by materials-balance methods. Since the amount of remaining oil and the reservoir pressure are now known, the remaining oil saturation can be calculated and the gas-to-oil permeability ratio K_g/K_o obtained from the data of Leverett and Lewis. This permeability ratio is next converted to free gas-oil ratio by adjusting for the viscosities and densities of the gas and oil phases. The total gas-oil ratio is equal to the free gas-oil ratio plus the gas in solution in the oil under reservoir conditions. If this calculated gas-oil ratio does not agree with the assumed ratio, the calculation is repeated using a different assumed ratio. When a satisfactory solution has been obtained for one step, additional oil and gas are withdrawn from the reservoir and the calculations repeated. This stepwise method is followed throughout the life of the reservoir.

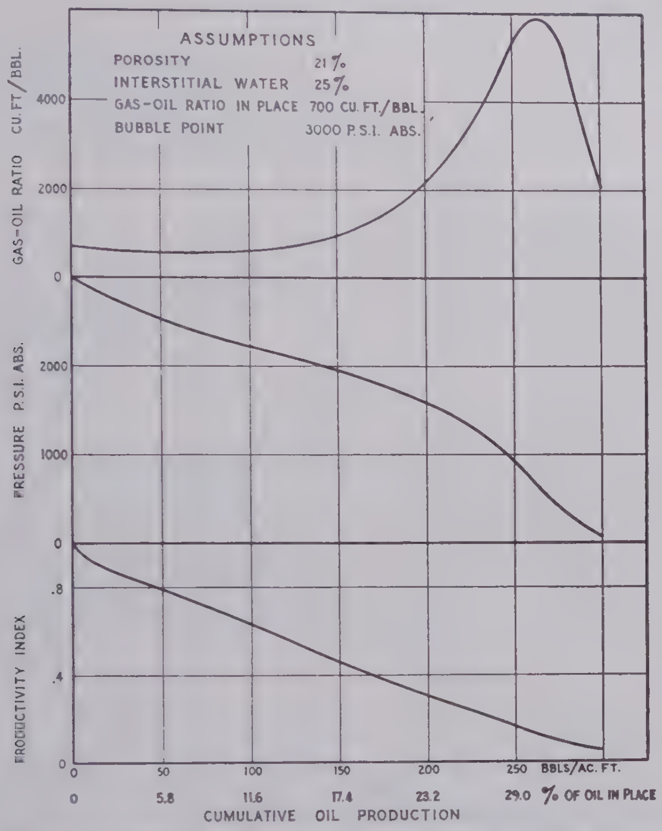

FIG. 2.—DEPLETION HISTORY OF A RESERVOIR PRODUCED AT VERY LOW DRAWDOWNS.

Results of these calculations are shown in Fig. 2, in which gas-oil ratio, pressure, and productivity index are plotted against recovery. In an effort to approximate at least some of the effects of finite pressure differential, the productivity index has been corrected for small differentials, starting with 100 lb. per sq. in. initially and gradually increasing to 320 lb. per sq. in. at a static pressure of 335 lb. per sq. in. According to Fig. 2, the gas-oil ratio first decreases from 700 to 550 cu. ft. per barrel, then rises to a peak of 5900 cu. ft. per barrel, and finally drops off rapidly. The decrease in ratio during the early stages of production is caused by the almost negligible permeability to free gas at low gas saturations together with the decreasing quantity of gas dissolved in the produced oil as the pressure drops. In other words, most of the gas that comes out of solution during the early stages of production is stored in the sand. The final decrease in gas-oil ratio is the result of the increased volume occupied by gas at low pressures: The volume ratio of gas to oil in the formation is continuously increasing but the standard cubic feet of gas per barrel of oil decrease. When 293 bbl. per acre-foot have been recovered, the reservoir pressure is 145 lb. per sq. in. and, if the original productivity index is assumed to be 1.0, the current productivity index will be 0.06. This corresponds to a maximum productive capacity of about 8 bbl. per day, which probably is close to

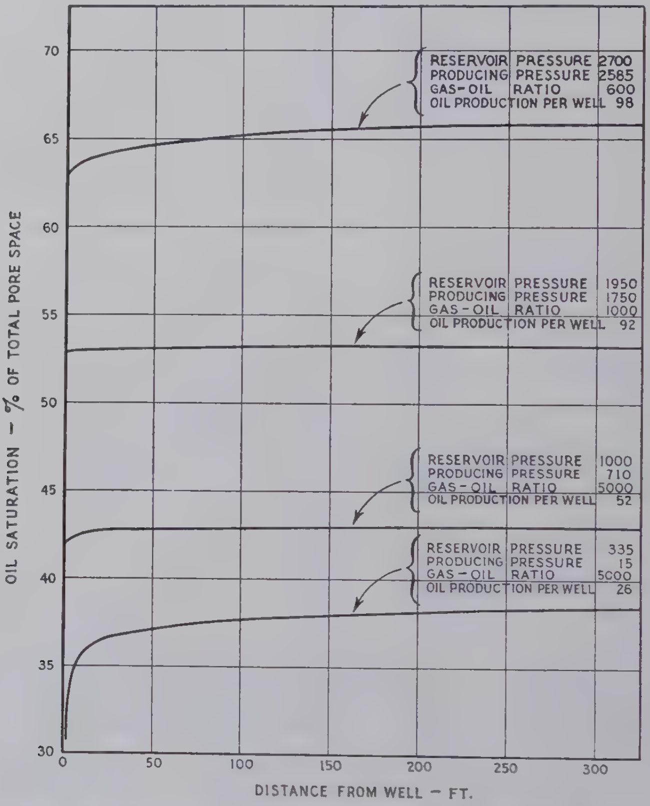

FIG. 3.—SATURATION DISTRIBUTION AT VARIOUS STAGES OF DEPLETION HISTORY SHOWN IN FIGURE 2.

the economic limit. Thus the recovery by internal gas drive is approximately 293 bbl. per acre-foot, or 34 per cent of the original oil in place.

In comparison with field performance, the gas-oil ratio curve of Fig. 2 seems to remain at a low level for an unusually long period. These low gas-oil ratios result in a flatter pressure-decline curve and greater ultimate recovery than is generally obtained in pools of this character. It is difficult to determine how much of this discrepancy is due to the effects of high pressure differentials and how much is caused by differences between California producing sands and the sand used by Leverett and Lewis. Since the discrepancies introduced by finite differentials would be reflected in saturation gradients in the sand, the saturation distribution in the sand was calculated at four stages of the depletion history shown in Fig. 2, using a well radius of 4 in., a drainage radius of 400 ft., and the drawdowns assumed in correcting the productivity indices of Fig. 2. The results of these calculations are shown in Fig. 3, together with the pertinent data. It can be seen that the saturation gradients are very flat except in the very early and very late stages of depletion. These results indicate that, at the low rates of production assumed, reservoir performance might approach that shown in Fig. 2. This evidence, however, is far from positive proof even for low rates, and at the high pressure differentials often encountered in field practice, important discrepancies may be introduced.

EXTERNAL GAS DRIVE

Oil is recovered by external gas drive if a gas front is caused to advance through the sand, displacing oil ahead of it. Partial gas-drive recovery can be attained by allowing a gas cap to expand but complete recovery by external gas drive requires the injection of gas to maintain pressures above the bubble point. In a reservoir produced by internal gas drive the entire reservoir is depleted more or less gradually. If the oil is displaced entirely by external gas drive, however, the portion of the reservoir behind the gas front is almost fully depleted while the portion ahead of the front is undepleted. Thus wells ahead of the front produce without decline, while those behind the front may suffer an almost complete loss of oil productivity. The problem of estimating the recovery ahead of a gas front can be reduced to an estimation of the distribution of oil saturation behind the gas front. Once the average oil saturation behind the front has been determined, the calculation of recovery is simple.

A method proposed by Buckley and Leverett[8] has been used in this paper. Their method is based upon the assumption that flow is steady with respect to the total volume flowing. This assumption requires, in turn, either that the fluids in the reservoir be incompressible or that the pressure be constant over the entire system. For the case of linear flow their basic equation is

$$\Delta u = \frac{Q_g}{\phi A} \frac{df_g}{dS_g} \qquad [4]$$

where Δu is the distance moved by a plane of fixed gas saturation during the time that a total volume of gas Q_g enters the system. The relation between the percentage of free gas in the flowing stream, f_g, and the gas saturation, S_g, can be established from the following equation:

$$f_g = \frac{100}{1 + \frac{K_o \mu_g}{K_g \mu_o}} \qquad [5]$$

since the gas-to-oil permeability ratio K_o/K_g is a function of the oil and gas saturations only.

In order to illustrate the method, calculations for external gas drive at 3000 lb. per sq. in. abs., will be outlined in some detail. First f_g is calculated for several values of S_g by using the data of Leverett and Lewis in Eq. 5. These values of f_g are plotted against the corresponding values of S_g as shown in Fig. 4. The slope of this curve is then plotted as a function of S_g, giving the peaked curve of Fig. 4. If it is now assumed that some arbitrary volume of gas is injected, say 21 cu. ft. (at reservoir conditions) per square foot of cross-sectional area, Eq. 4 states that the distance moved by a plane of given gas saturation can be found by multiplying the value of $\frac{df_g}{dS_g}$ at the given saturation by 21/0.21, or 100. As the original gas saturation of the reservoir was zero, each of these calculated distances is measured from the plane of entry of the gas. Application of this procedure results in the curve of Fig. 5, which is the same as the $\frac{df_g}{dS_g}$ curve in Fig. 4 except for a change of scale. Since it is impossible for two different gas saturations to exist at the same point, and since the total area under the curve must equal the total volume of gas entering the system, divided by the porosity and the cross-sectional area, the dotted portion of the curve is considered to be imaginary, and a horizontal line representing the gas front is drawn at such a position that the shaded area in Fig. 5 is equal to 21/0.21 or 100. The average gas saturation behind the front is 36.6 per cent, which corresponds to a recovery of 420 bbl. per acre-foot from the area swept by the front. If a larger quantity of gas is injected, all the values of $\frac{df_g}{dS_g}$ are multiplied by a new

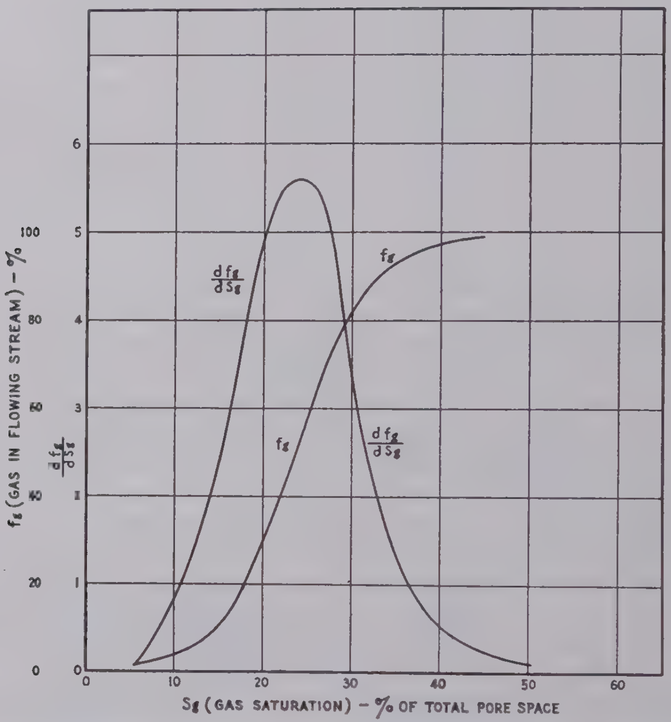

FIG. 4.—PRELIMINARY STEPS IN CALCULATION OF SATURATION DISTRIBUTION BEHIND AN ADVANCING GAS FRONT AT A PRESSURE OF 3000 POUNDS PER SQUARE INCH ABSOLUTE.

constant so the curve of saturation as a function of distance will be identical with the curve of Fig. 5 except for a change of scale. Thus the average gas saturation behind the front is independent of the distance the front may have traveled. Furthermore, it can be shown that the average saturation will be the same for the radial flow case.

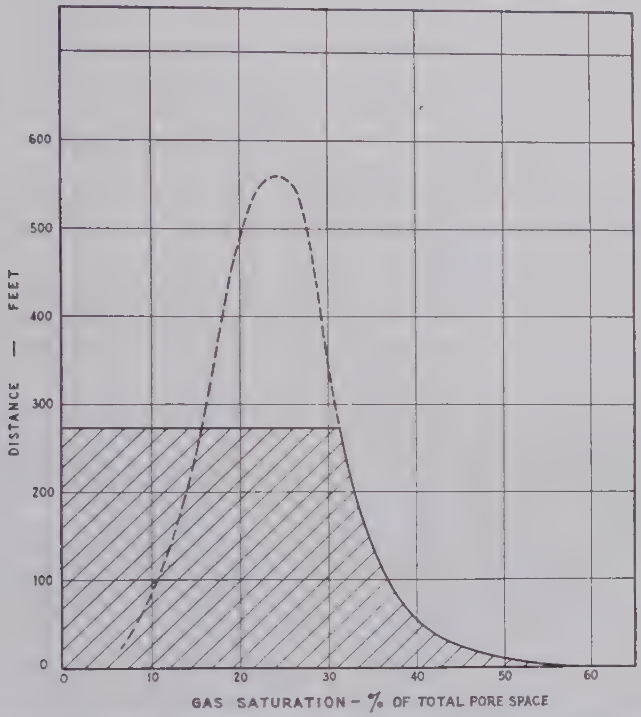

FIG. 5.—SATURATION DISTRIBUTION BEHIND AN ADVANCING GAS FRONT AT A PRESSURE OF 3000 POUNDS PER SQUARE INCH ABSOLUTE.

Capillary forces will cause an actual gas front to be somewhat less abrupt than that shown in Fig. 5, but the error involved is probably small. As the front passes a well, the gas-oil ratio will rise rapidly from 700 to 8800 cu. ft. per barrel and will then rise more slowly as the front continues its advance. The average gas-oil ratio of all wells in the area swept will be approximately 20,000 cu. ft. per barrel. Because of high gas-oil ratios and high injection pressures, it is obvious that recirculation of gas will not be economically feasible, and wells must be shut in soon after the gas front passes them. If no gas is recirculated, full pressure maintenance requires the injection of 1370 cu. ft. of gas per barrel of oil produced. After the gas front has passed all the wells, the reservoir will contain 800 M cu. ft. of high-pressure gas per acre-foot, most of which can then be produced and sold. Oil recovery during this period can be estimated by the method illustrated in Table 1. If all the wells are produced, recovery from this phase of production is estimated to be 15 bbl. per acre-foot, while if most of the production is taken from wells last passed by the gas front, the recovery might approach 25 bbl. per acre-foot. This gives a total recovery of 435 to 445 bbl. per acre-foot, all of which should be obtainable by flowing or straight gas lift.

A word of caution is necessary at this point. Even if all the calculations in this paper are applicable without modification to California oil sands, the additional recovery due to pressure maintenance is obtained only from that portion of the sand actually swept by the gas front. The remainder of the sand will not produce more than 293 bbl. per acre-foot and may conceivably produce somewhat less. For this reason the gas front must sweep out a major portion of the reservoir in order to ensure an appreciable increase in recovery. It is not within the province of this paper to discuss the difficulties involved in pressure maintenance operations, but adequate control of gas fronts in a typical California oil field is an engineering problem of major proportions.

If the gas-drive operation is conducted after the reservoir pressure has been allowed to fall to 2000 lb. per sq. in., the average gas saturation behind the gas front is 35.1 per cent, which gives a total recovery of 336 bbl. per acre-foot from the area swept. If the operation is conducted at pressures lower than 1500 lb. per sq. in., the gas saturation resulting from normal depletion will be so high that there will be no true gas front. Producing gas-oil ratios will begin to rise almost immediately and recirculation of gas will be necessary. It is extremely difficult to estimate the additional recovery to be obtained in this manner, because of a most complex interrelation between physical and economic factors in this lower pressure range, but it seems unlikely that large quantities of oil could be recovered from the assumed reservoir by this method.

The low recovery from external gas drive at low pressure in this reservoir probably is due to the relatively efficient primary recovery by internal gas drive. If the primary recovery operation had been less efficient, owing either to lower original pressures or to wasteful production practices, important quantities of oil might be recoverable by low-pressure gas drive.

WATER DRIVE

Recovery by water drive has been estimated by a method similar to that used for gas drive. If the water drive is operated at the original reservoir pressure of 3000 lb. per sq. in., the recovery ahead of the water front is estimated to be 545 barrels. per acre-foot from the area swept. The production from a well passed by the front will contain 84 per cent water, and if production is continued, an additional 35 bbl. per acre-foot can be recovered before the water content of the well effluent reaches 90 per cent. The method

TABLE 1.—*Sample Calculation of Depletion History by Internal Gas Drive at Very Low Drawdowns*

Given: Porosity, 21 per cent
Total pore volume = $0.21 \times 0.7758 = 1630$ bbl. per acre-foot
Interstitial water = 25 per cent
Net pore volume = $(1 - 0.25)\ 1630 = 1223$ bbl. per acre-foot
Initial formation volume factor = 1.42
Oil in place = $\frac{1223}{1.42} = 860$ bbl per acre-foot
Initial pressure = 3000 lb. per sq. in. abs. = bubble point
Temperature = 210°F.
Initial gas-oil ratio = 700 cu. ft. per barrel

Calculation:	*A*	*B*
1. Assumed oil production, bbl. per acre-ft	20	20
2. Assumed average gas-oil ratio, cu. ft. per bbl.	680	662
3. Remaining oil 860 − (1), bbl. per acre-ft.	840	840
4. Calculated pressure, lb. per sq. in. abs.	2,775	2,785
5. Formation volume factor of liquid	1.365	1.367
6. Oil saturation (3) × (5)/1630, per cent of total pores	70.4	70.5
7. K_g/K_o (after Leverett and Lewis)	0.0005	0.00045
8. Conversion factor ($\rho\beta\mu_o/\mu_g$), cu. ft. per bbl.	32,500	32,600
9. Free gas-oil ratio (7) × (8), cu. ft. per bbl.	16	15
10. Dissolved gas-oil ratio, cu. ft. per bbl.	607	612
11. Total gas-oil ratio (9) + (10), cu. ft. per bbl.	623	627
12. Average gas-oil ratio 700 + (11)/2	661.5	663.5

In calculation *B* the calculated gas-oil ratio is 663.5 while the assumed ratio is 662.
This is a satisfactory solution.

used in this paper is not rigorously applicable to a water drive at any pressure below the bubble point because of the complications introduced by variable gas saturation. In order to approximate the recovery to be expected at 400 lb. per sq. in., it was assumed that the gas saturation behind the front would be constant at 5 per cent. Recovery ahead of the front then becomes 405 bbl. per acre-foot and the recovery to 90 per cent water in the well effluent is 472 bbl. per acre-foot.

TABLE 2.—*Summary of Recovery Calculations*

Method of Depletion	Total Recovery	
	Bbl. per Acre-ft.	Per Cent
Normal depletion (internal gas drive)	293	34
Full pressure maintenance (external gas drive at 3000 lb. per sq. in. plus subsequent depletion)	435	51
Partial pressure maintenance (external gas drive at 2000 lb. per sq. in. plus subsequent depletion)	348	41
Water drive at 3000 lb. per sq. in.	580	68
Normal depletion plus water drive at 400 lb. per sq. in.	472	55

Although these recoveries seem high, it must be remembered that they apply only to the area swept by the water. In the low-pressure drive, normal recovery was obtained from the reservoir before the flood started, so that only the additional recovery from the unswept area is lost. In the high-pressure drive, however, it seems unlikely that normal recovery can be obtained from portions of the reservoir unswept by water because dewatering a flooded sand is a costly operation.

SUMMARY

Results of the various recovery calculations, which are summarized in Table 2, should be regarded as examples of the type of information obtainable from laboratory data rather than quantitative predictions of the behavior of California reservoirs, since the data entering into these calculations are applicable only to the particular sand on which the laboratory tests were made. Permeability-saturation relations for California oil sands under reservoir conditions are not yet available in the literature, hence it is impossible at present to make reliable predictions of field performance from laboratory data. The preliminary investigation reported in this paper, however, suggests that future application of such information may furnish workable solutions to some of the perplexing problems facing the industry.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Howard C. Pyle for his advice and guidance and to the management of the Union Oil Co. for permission to publish this paper.

NOMENCLATURE

I	Productivity index, bbl. per day per lb. per sq. in.
P	Pressure, lb. per sq. in. abs.
μ	Viscosity, millipoises.
β	Formation volume factor of oil phase, bbl. per bbl.
K	Permeability, darcys
ρ	Density of gas, std. cu. ft. per bbl. space.
R	Total gas-oil ratio, std. cu. ft. per bbl. oil.
M	Dissolved gas-oil ratio, std. cu. ft. per bbl. oil.
Q	Total volume, cu. ft.
ϕ	Porosity, fraction.
A	Cross-sectional area, sq. ft.
f	Proportion of displacing fluid in flowing stream, per cent by volume.
S	Saturation, per cent of total pores.
u	Distance, ft.

Subscripts:

o	refers to oil phase.
g	refers to gas phase.
e	refers to conditions at drainage radius.
w	refers to conditions at the well face.
1	refers to arbitrarily chosen standard conditions.

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Gravity Drainage in Oil Fields

By James O. Lewis,* Member A.I.M.E.

(Austin Meeting, October 1942)

Abstract

Gravity drainage is the self-propulsion of oil downward in the reservoir rock. Under favorable natural and operational conditions, it has been found to effect recoveries comparable to water displacement. With modern technical knowledge, the operator can often make a choice between dissolved gas drive, water drive and gravity drainage as the principal recovery agent in a reservoir. It is desirable that the operator be able to determine which of the three agents will be most effective under each set of conditions. So far, gravity drainage has received less consideration than the other two. In this paper, an endeavor is made to set forth some of the principles of gravity drainage, to point out the types of reservoirs favorable for it, and to show how it may be applied in them. Field examples are described and discussed.

Introduction

Since early in the history of the oil industry, it has been recognized that gravity is one of the three important natural forces for expelling oil from the reservoir rock. As knowledge of the technology of oil recovery progressed, ideas changed with respect to the relative importance of the three forces and with respect to the manners in which they functioned. For a time, disproportionate emphasis was placed on the importance and function of gas and the need for conserving gas pressures. More recently, disproportionate emphasis has been placed on encroaching edge water. Only lately has there been evidence that the function and importance of gravity was to receive due consideration.

Study of this neglected phase of oil recovery is needed to round out our knowledge of reservoir behaviors and to gain a balanced viewpoint of the interplay of forces that may operate in varying importance in reservoirs. The purpose of this paper is to discuss mainly in a qualitative way, the functions of gravity, to present some concrete instances where it has been important and to raise some questions that should be investigated further.

Oil-recovery Agents

The important natural agents for effecting oil recovery that may be originally available in a reservoir are gas, both dissolved in the oil and free in gas caps, encroaching edge water and gravity. Each of these agents can act in a dual capacity—physically to overcome the surface energies that hold the oil within the pores and mechanically to overcome viscous resistance and to propel the oil through the porous reservoir rock to the wells. Advancing edge water displaces the oil from the pores and lifts it updip to structurally lower wells. Gravity drains the oil from the pores and flows it downdip to the wells. Gas displaces oil from the pores, entrains it in the gas stream and flows it to the wells, but gas in solution also affects the physical properties of the oil and thus can influence oil recovery by the other agents, whether or not the mechanical energy in the gas is utilized.

Of the two functions of these agents, the more important is the ability to dis-

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place the oil from the pores, for this sets a limit to oil recovery.

It is difficult to differentiate between these two functions but they may be illustrated by comparing flow through pipe lines with the flow through sand. A pipe has relatively little surface area whereas sand grains have an enormous total surface area. The chief function of the agent in moving oil through the pipe is mechanical, but in a sand the chief function is to overcome the interfacial forces at the sand surfaces and to separate the oil from them. As the surface forces are least in the centers of the pores (Fig. 1), the small portion of the oil central to the pores can be removed easily. Gas, which is a poor displacing agent, can remove a small part of the oil with little expenditure of energy but it takes enormous gas energy to remove a large percentage. This may be contrasted with water and gravity, which are relatively good displacing agents. Gravity, with a trifling expenditure of mechanical energy, can drain a large percentage of oil from a sand. The important fact is not how much potential mechanical energy is in the reservoir but how effective it will be in displacing the oil. It is misleading to compare recovery agents in terms of reservoir energy and to consider reservoir energy solely in the usual terms of pressure, force or work.

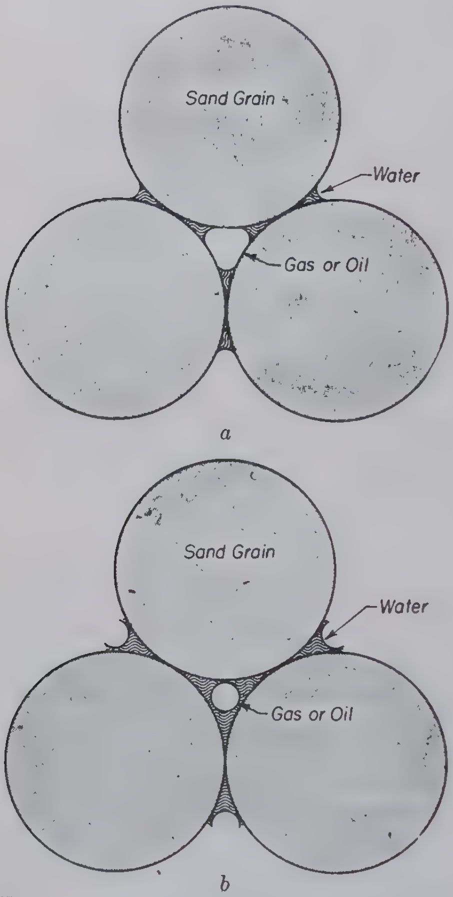

FIG. 1.—SATURATION RINGS IN A CAPILLARY SYSTEM. (*From M. C. Leverett.*[2])

Of the three important agents for oil recovery, the only one that is always present, and that can occur without the others being present, is gravity. Gas is almost always present in solution originally but the amount of gas energy accompanying each barrel of oil will vary widely and may be entirely lacking in an old, depleted field. Free gas in a gas cap occurs rather frequently. In the majority of reservoirs, the oil pool is bounded at least in part by edge water, which usually encroaches to some extent and sometimes is capable of completely refilling the reservoir space vacated by the removal of oil and gas. The relative mechanical energies contained in these three agents vary widely between pools but almost always gravity, which is used here as a measure of the force developed by the hydrostatic head of oil in the reservoir, is the feeblest.

However, the relative importance of these agents is not to be measured in terms of their potential mechanical energies alone but in terms of their over-all effectiveness in moving oil from the pores into the well. For the most part, these three forces interfere with each other rather than cooperate and usually only one can be used effectively at one time at the same place in the reservoir. The invasion of edge water is opposed by the gas pressure and by the weight of the oil column, though gravity aids edge-water drive by leveling up the oil-water front. The expansion of solution gas tends to nullify the effects of gravity, though the gas in the gas cap can be used within limits to augment gravity. In the main, however, efficient use of one of the agents necessitates the nonuse of the other two.

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[2] References are at the end of the paper.

Which one of these agents is locally dominant depends upon local natural and operating conditions. It is possible to have in the same pool water as a dominant agent along the water contact while gravity is dominant in another part of the pool and gas drive in still another part. It is also possible for a pool to pass from one dominance to another. Under old methods of unrestricted flow, usually the gas drive was dominant in the early life of a pool, but later either water drive or gravity drainage might become dominant. These changes from the dominance of one agent to another are indicated in some of Miller's curves,[1] where cumulative oil recovery is plotted against cumulative loss in reservoir pressure.

CAPILLARITY

The downward flow of oil through a reservoir rock under the influence of gravity is not fully analogous to free flow in a pipe, for, with the exception of some limestone reservoirs with macroscopic pores or fractures, oil flow is through devious channels of capillary size. The self-propulsion of oil downward through a sand under the impulse of its own weight occurs in two zones. At the top, where the liquid is in contact with free gas, the sand is only partly oil saturated and capillarity controls the flow. Below the base of this capillary zone, which corresponds to a free surface, the sand is saturated or nearly saturated with liquid, and flow follows hydraulic laws.

Usually gas, oil and water are present together in the capillary zone in a reservoir, but for simplicity, discussion of the influence of capillarity on gravity drainage is first confined to the assumption of a water-free sand.

Oil in contact with a column of dry sand will rise upward above the liquid surface till the pull of the capillary forces becomes balanced with the pull of gravity. Leverett[2] describes the liquid saturation in an air-water system, which would be the same qualitatively as gas-oil system, as follows:

> Smith, Keen, Versluys and others have pointed out that there are three general types of occurrence of water, or regions of water saturation in a porous solid:
>
> 1. Saturation region. Complete water saturation.
>
> 2. Pendular region. Lowest water-saturation range. Water occurs as pendular rings around grain-to-grain contacts. The solid, where not covered by water in the pendular rings, is covered with a very thin film of water if the contact angle is zero, or by oil if not. Fig. 2*a* illustrates this saturation region.
>
> 3. Funicular region. Intermediate water saturation. Addition of water to the pendular rings of Fig. 2*a* causes them to grow and soon they become so large that they touch each other at their edges and merge. * * * * Addition of still more water causes complete coalescence of the funicular rings, the results being a web of water across the interspace between three or more grains. Both of these configurations are included in the funicular saturation region, since in either case it is possible to pass from any position in one fluid to any other in the same fluid by a tortuous, cordlike (funicular) path through that fluid.
>
> The nomenclature is that used by Versluys.

The conditions in the pendular and funicular regions are shown in Leverett's Fig. 2, which is here reproduced as Fig. 1.

The junction of the saturation and funicular region corresponds to the free water surface.

Leverett describes another region in which "air exists as globules surrounded by water," but he thinks this is "thermodynamically unstable; it is believed that they tend to disappear by solution in the water and subsequent diffusion to more stable positions."

The writer believes it would be useful to recognize this fourth region in reservoir performance, for which he uses the term "Insular Region" in this article. This region has already been recognized in oil literature as one through which the reservoir passes when pressures are first reduced below gas-solution pressure. The first gas that evolves forms minute globules of gas in the pores held apart by interfacial forces. As pressures are reduced still further, the globules grow until they touch and a condition similar to the funicular region develops. The writer found no references discussing what effect the insular region has on the free surface but he thinks it would be at the junction of the insular and funicular regions. Apparently it is in this insular region that free gas can exist in the pores of a sand and yet the sand not be permeable to gas flow; and apparently, too, these free gas globules are entrained in the oil stream and perhaps in part can be moved downward through the pores of the sand if the oil is moving in that direction (Fig. 2).

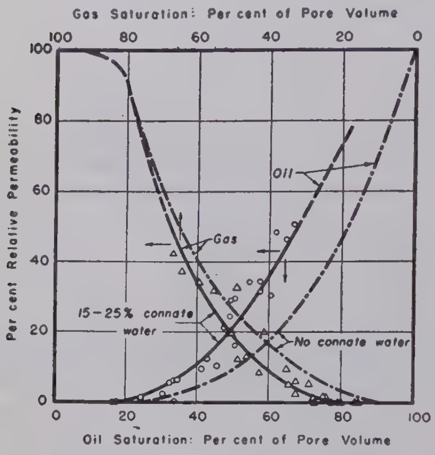

FIG. 2.—GAS, OIL AND WATER PERMEABILITIES.
From Leverett and Lewis: *Trans.* A.I.M.E. (1941) **142**, 114.

Within the range of pressures less than solution pressures in which the insular region can occur, the free gas is incorporated into the liquid stream and the effect is to make the oil a more expansible liquid. During this period, well gas-oil ratios would not exceed existing solution ratios, hence estimating the solution pressure by the pressure at which gas-oil ratios started to increase can lead to underestimation. When the pressures are reduced below this region, gas-driven conditions can begin.

Whether oil could occur in a reservoir in the insular region at the time of discovery should be considered. Reservoir pressures can change within geologic time, some increasing, some decreasing in accordance with whether the reservoir is in a submergent or emergent portion of the earth's crust. If the reservoir is in an emergent area, where pressure has been reduced to below previous gas-saturation pressure, an insular region would develop, and because the oil surrounding each globule of gas would be gas saturated, the globules would not readily disappear by solution and diffusion. In absence of agitation, solution and diffusion are known to be exceedingly slow and instances are coming to light in some gas fields where diffusion between gases of different character has not been reached even in geologic times—notably between the sour and sweet gases in the Amarillo field. If such a condition can exist, allowances would have to be made for it in estimating reserves where there is reason to believe the insular region can occur.

When oil is imbibed into the bottom of a column of dry sand, capillarity will raise it only to a limited height, above which the sand will contain no oil, but if the sand column is first saturated with oil and then drained, all parts of the sand will contain some oil and the pendular region will extend upward in the sand column as far as it had once contained oil. Leverett shows that, because of hysteresis, more oil will be held in the funicular region in such a drained sand than in a sand into which the oil has risen under capillary pull.

It is this pendular oil, together with the oil in the thinner belt of the funicular region, that would be irrecoverable in a reservoir with homogeneous sand. Leverett's curves show from 5 to 25 per cent of water retained in this pendular region under drainage equilibrium in the sands with which he experimented. Katz[3] found that from 5 to 20 per cent of the oil would be retained in the water-free Wilcox sands of Oklahoma City. Katz also states that oil and water may "drain of their own accord down to a final saturation of 8 to 10 per cent in the upper portion of thick sand sections." The sands to which these figures apply had high permeabilities, and sand of finer pore size and lower porosities will retain larger percentages of the liquid in this region after drainage. Moreover, such fine-pored sands will drain at slower rates. Viscous oil will drain at slower rates and more will be retained in the pendular region.

Liquid saturation above the free liquid surface in a specific sand is controlled by the vertical distance above the free surface rather than by the distance along the slope of the sand. However, the slope will have much influence on the rates at which oil can drain downward, especially in thinly bedded sands, both in the funicular region and in the fully saturated region. In sands of low dip and fine pores and having low vertical permeabilities, the rates of drainage can be noncommercially slow and gravity drainage will then be ineffective, no matter how much of the oil might be drained out in course of unlimited time.

Greater capillary force is developed in the smaller pores; therefore, they will retain oil against the lesser capillary pull in contiguous pores of larger size. The more irregular is the sand body, the more oil will be retained in the pendular region after drainage. Where two sand strata of differing capillarity are separated by impermeable material, the two strata will not influence each other but gravity drainage in them will act like two independent systems.

In most reservoirs, the sands will be water wet instead of oil wet, as assumed in the preceding discussion. Leverett states that the gas-oil-water system has not been adequately investigated but he shows that where water preferentially wets the sand it causes a shorter funicular zone between the liquid-saturated region and the pendular region.

Capillary Systems in Motion

The theory and experimental data discussed so far apply to a capillary system in which the free surface is lowered in one stage, after which the system is allowed to reach equilibrium.

When a sloping sand bed in a reservoir is being drained by wells downdip of an unreplenished supply of water or dead oil, there is a continuous lowering of the free surface. With such a moving capillary base, static equilibrium in the capillary zone would not be reached. There would be two zones of motion. Below the free surface, the sand would be completely filled with liquid and the flow would follow the usual hydraulic laws described by Muskat[4] and others; above the free surface, the flow would be in the capillary zone, which would follow downdip as the free surface was lowered. The capillary zone itself would consist of two parts. In the funicular region, liquids would be in motion but in the upper part, which had completely reached the pendular zone, the liquids would be immobile.

Leverett,[2] Hassler,[5] Stahl[6] and others have shown that when the free surface in a sand is lowered in one stage and the water or dead oil are allowed to drain until equilibrium has been reached, there will be a definite curvature of diminishing saturation upward from the free surface for each particular sand and liquid system (Fig. 3). In a sand with large pores, the height of the curve between complete saturation and the pendular region in which no more liquid can be drained out will be only a few inches, whereas it can be several feet in a sand with fine pores.

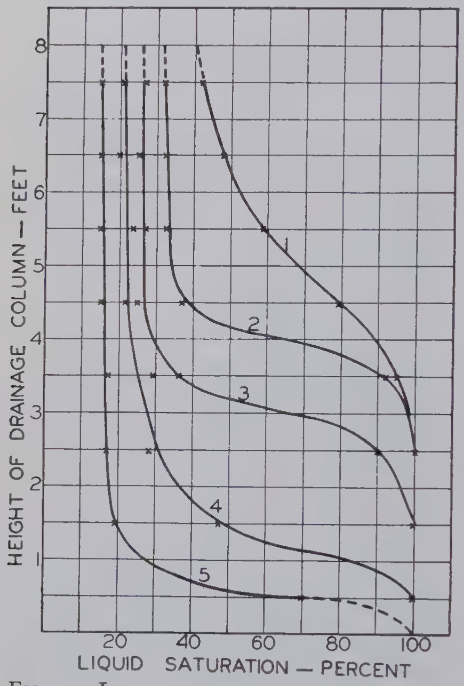

FIG. 3.—LIQUID SATURATION IN A CAPILLARY SYSTEM. (*Stahl, Martin and Huntington.*[5])

The effects of a lowering free surface should be to stretch out this curve of upward diminishing saturation and this funicular zone of partly drained sand could be much thicker than shown by the saturation curve of a capillary zone that was in a state of rest (Figs. 3 and 4). It would also appear that the faster the liquids were being withdrawn from below the free surface, the more this partly saturated capillary zone would be stretched out, and that it would tend to stretch out more both vertically and along the bedding when the sands were dipping at low angles. The oil left behind by fast drainage would eventually drain downdip at slower rates but probably in most oil reservoirs much of it will be at rates too slow for commercial recovery.

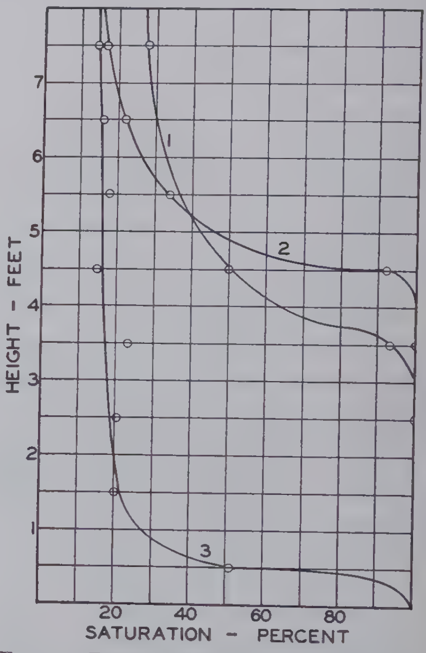

FIG. 4.—READJUSTMENT OF LIQUID SATURATION AFTER A REST PERIOD IN A CAPILLARY SYSTEM. (*Stahl, Martin and Huntington.*[5])

That the saturation curve in the capillary zone would be stretched out in the manner described is shown by Stahl and Huntington's Fig. 3, which is reproduced here as Fig. 3. It is apparent that liquids do not drain at a uniform rate in all parts of a capillary system and that drainage is progressively slower upward from the bottom. The more depleted are the pores, the slower will be the rate of drainage. Capillary systems in motion have not been adequately investigated.

In the saturated zone where the oil flow will follow well-known hydraulic laws, the flow rate is largely at the control of the operator, who can change rates by varying pressures, the production rates of wells and the number of well outlets. Rates of drainage in the funicular zone are less subject to control; therefore the elongation of the funicular zone must be controlled mainly by the rates of withdrawals below the free surface.

EFFECT OF GAS PRESSURE ON GRAVITY DRAINAGE

Gravity drainage can take place in the capillary zone of a sand at any gas pressure from less than atmospheric to very high pressures. No information is available to the writer on whether capillary drainage would be faster in a sand filled with high-pressure or low-pressure gas, irrespective of the effects of gas in solution on the physical properties of the oil. However, as the physical characteristics of oil are changed by natural gas in solution, it may be presumed that there will be important differences in capillary effects at different pressures. Entirely apart from the actual use of the mechanical energy of high-pressure gas in solution, it should have favorable physical effects on the extraction of oil from the pores. Lowering pressures will cause gases to be evolved from solution and finally to vaporize and to remove volatile constituents that will progressively increase viscosity and adhesion, thus delaying drainage and causing it to be less complete.

SEGREGATION OF GAS FROM OIL

Under original conditions, there will almost invariably be gas in solution in the oil. If the original pressures are reduced, the gas will begin to come out of solution and to expand, some of the oil will be driven from the pores by the freed gas and partial saturation conditions will be developed corresponding to the insular and funicular regions in a capillary system induced by gravity drainage. At first, the minute globules of gas will be in the insular region, each centered in its pore and separated from all other gas globules by oil. At this stage, the sand is lacking in gas permeability, the gas is entrained in the oil and probably will move with the oil stream (Fig. 2). In effect, single-phase flow would still exist in the sand and the freed gas would merely reduce density and impart greater elasticity to the liquid. Flow probably would follow the usual laws of hydrodynamics and would be modified only by the changed properties of the flux; i.e., greater elasticity and reduced density.

The next stage is reached when, after the pressures have been reduced still further, the gas globules become enlarged until they connect between pores. This stage corresponds to the funicular region and the sand then becomes permeable to both gas and oil, the relative gas permeability increasing as the sand becomes progressively depleted of oil. The funicular-like region developed in this manner can occur in any or all parts of the oil reservoir but it is unstable and is sustained by the velocity of the gas moving through the pores.

Depending upon the velocity of gas flow and the relative gas-oil saturation, the oil can either be propelled in any direction by the gas at high gas velocities, or at low gas velocities the oil can flow downward under gravity and displace the gas, causing the gas to flow to higher levels. The critical gas velocity at which such counterflow can occur in a sand is of much practical importance. Above this velocity, dissolved gas-drive conditions will prevail and below it gravity drainage will prevail and the free gas and oil will segregate, the gas making its way to the higher parts of the reservoir and the oil to the lower parts. The downward flow of the oil will be greater at slower upward flow of gas.

The gas velocity at which through counterflow gas and oil can segregate and gravity drainage begin will vary with specific conditions. Sands with large pores, good vertical permeability and high dips are favorable for counterflow, as are oils of low viscosity. As oil saturation decreases, the gas can segregate more readily and it is less likely to entrain oil, but, on the other hand, oil will drain less rapidly under the pull of gravity. Evidently the interrelation of these factors can be quite complex, hence it will be difficult, if not impracticable, to evaluate them numerically in any reservoir.

As the values of these factors will vary within the reservoir, the gas velocity at which gas can segregate from and not entrain oil will not be uniform throughout the reservoir. Differences can occur within short distances. Sands can vary in their properties between layers as well as along the bedding. Such irregularities may provide channels through which gas can by-pass just as in a secondary gas drive. But though irregularities may promote segregation locally, it will also cause irregular drainage of the sand body and create operating problems that in the end will make for less efficiency in ultimate recovery.

Also, there would be variable gas velocities in a producing reservoir even if sand conditions were uniform. A field is seldom drilled and depleted uniformly; moreover, velocities will vary widely within the drainage radius of each well, flow velocity being greatest near the well and least between wells.

Because of these variables, segregation and gravity drainage may be going on in certain parts of a reservoir while gas drive is going on in other parts not far distant. As the fluids in the depleting reservoir are in motion, unstably located gas caps can be formed where locally either sand conditions or velocities are favorable to early segregation, and these transient gas caps can be formed below the crest of the structure. Such local gas caps are likely to be formed between wells where gas velocities are least, but as such gas caps become larger, they could be expected to move updip unless trapped by changes in formations.

For the reservoir as a whole, the mean gas velocity will be controlled by the rate at which pressures are reduced. In a reservoir with nonencroaching edge water, gas velocities will be governed by the rate at which fluids are withdrawn and the proportion of the gas injected back into the reservoir. Obviously, oil can be produced most rapidly from a reservoir in which pressures are being maintained by gas injection and still have segregation and gravity drainage. This should be noted in considering primary pressure control.

It must be kept in mind that the velocities underground are infinitesimal compared with the surface velocities to which we are accustomed. A vertical drainage rate of 10 ft. a year in many reservoirs would yield oil at a satisfactory rate, yet the vertical velocity would be only ⅓ in. each day. Even the velocity parallel to the bedding in sands of low dip would be in inches per day.

Blowing Off the Gas from a Reservoir

If the pressures in a reservoir in which conditions are favorable for gas and oil segregation but not for edge-water encroachment are not regulated, but, instead, the wells are allowed to produce at fast rates without regard to structural location, the reservoir will be under dissolved gas-drive conditions until the gas has been so depleted that it can no longer act effectively as an expellant. At some stage in the depletion of such a reservoir, the velocity of the gas will become so low that it can no longer lift oil updip through the depleted sand pores, against the pull of gravity, which may then become the dominant agent in the reservoir. It is now known that in several pools where this blowing off of the gas took place, the gas and oil later segregated, low-pressure gas caps were formed in the upper part of the reservoir and the oil was drained down into the lower portions of the reservoirs.

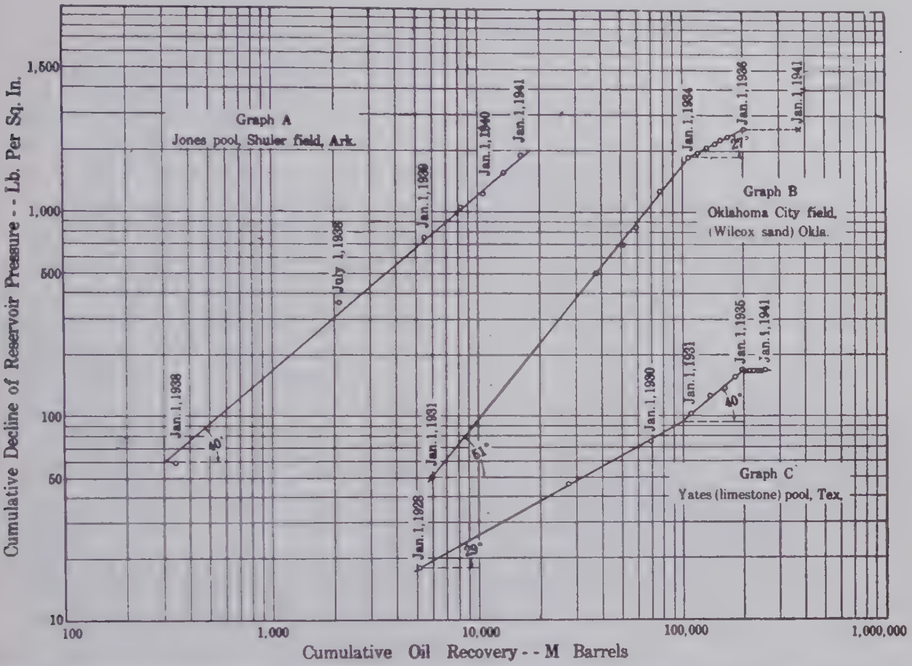

FIG. 5.—PRESSURE-DECLINE, OIL-RECOVERY RELATIONS IN WILCOX SAND, OKLAHOMA CITY POOL (*Miller.*[1])

By the time a reservoir reaches the stage of depletion at which the gas velocity can no longer overcome the pull of gravity and counterflow can begin, the oil will be dispersed throughout the sand body in a manner similar to that in the funicular region of the capillarity zone and this region will extend far above its normal capillary height. When the gas velocity can no longer sustain this unstable condition, it collapses as does foam over the surface of live oil when gas ceases to evolve and to support the bubbles. The oil then tends to form a stable capillary system. Oil will drain out of the higher portions of the structure to lower portions. In the higher portions, oil saturation will be reduced from funicular to pendular and in the lower portions increased from funicular to saturated, as shown by curve 2, in Fig. 4. At some level between, it forms a free surface with a normal capillary funicular zone above it. The pendular region becomes a low-pressure non-oil productive gas cap and the oil in the funicular and saturation zone thereafter moves downdip in accordance with the hydraulic laws as oil is produced from low wells.

The time and the rate for the adjustments that must take place when such a reservoir passes from gas drive to gravity drainage conditions will vary with local conditions. It will take much time for the oil to drain out of the higher parts of the structure to the lower under less favorable conditions of tighter sands at low dips. Owing to the variable natural conditions, variable pressures and gas velocities, the collapse will start in different parts at different times in the reservoir and proceed at different rates. This transition period will be one of confusion with anomalous conditions and events.

The transition period is clearly recognizable in the history of Oklahoma City and other pools. The evidence of Oklahoma City is shown by the change in trends in the curve given by Miller (Fig. 5) though in this case some effects are caused by limited encroachment of edge water. Miller shows in his analyses of various pools how, in the course of the history of pools, they can change; how at one period one force can be dominant and later another or even a third force may become the most important. In Oklahoma City, it began when the average pressure had been reduced to 750 lb. per sq. in. In another pool, it took place before the pressure had reached 250 lb. per sq. in. in the crestal area.

Spreading Gas Caps

However gravity-drainage principles are applied, it requires that a gas cap be formed and spread. Essentially, it is a method of exhausting the recoverable oil downward from a reservoir progressively from the crestal area down the flanks, leaving the drained part to be filled either with high-pressure or low-pressure gas. If an original gas cap existed, it will spread and if not, a secondary gas cap must form and spread. If a pressure higher than solution pressure is to be maintained, gas must be injected into the gas cap, which will spread by reason of the added quantities of gas and the removal of fluids downdip. If pressures are being lowered gradually, the gas cap will spread by reason of the expansion of the gas-cap gas and by additions from the upward flow of gas freed from solution from oil at lower levels in the reservoir, or perhaps by additions of gas injected into the reservoir. If the gas is first blown off, there will be a gas cap of very low pressure. The sand in the original gas-cap area may have almost no oil in the sand but the portion of a gas cap formed by draining sands that once were oil saturated will contain pendular oil that cannot be drained out or removed by gas or water drive.

The mere fact that an original gas cap appears to be spreading does not necessarily mean that gravity drainage is working effectively. If the wells in the oil rim below the cap are produced at too fast a rate, dispersed gas-drive conditions will prevail and the gas cap then becomes an additional source of energy to maintain the gas drive. The wells near the gas cap will develop high gas-oil ratios yet the sand will not be effectively drained of its oil and the oil will be moved mechanically by the gas flow instead of draining downdip under gravity pull. Under true gravity-drainage conditions, the gas refills voids caused by the withdrawal of oil. Gravity drainage in the capillary zone sets the pace, which must not be exceeded if dispersed gas-drive conditions are to be prevented.

In distinction from dissolved or dispersed gas-drive conditions where oil and free gas become intermingled and dispersed throughout the reservoir, it is sought to keep the oil and free gas separated into two distinct masses or zones as they were originally in a gas-cap reservoir. The purpose is to increase the mass of free gas at the top while withdrawing the oil below until finally the gas cap takes the whole reservoir. To maintain the oil and free gas in separate zones, it is necessary that two limiting rates be not exceeded. The pressures must be reduced so slowly that the evolved gas can flow countercurrent with the oil, otherwise dissolved gas-drive conditions will develop. The oil must be withdrawn so slowly that gravity can drain the oil effectively from the pores and can maintain the gas-oil front, otherwise the gas-cap gas will break into the oil mass and cause dispersed gas-drive conditions. Effective application of gravity drive principles means slow but steady production, especially in irregular sand bodies. These two rates are interdependent. The upward counter flow of evolved gas will retard the downward flow of oil, elongate the funicular region and interfere with the maintenance of the front between the two masses. It would appear that the nearer pressures can be maintained to solution pressures, the less will evolved gas interfere with the desirable functions of gravity, and that oil can be taken from below the gas-oil contact at faster rates without causing dispersed gas-drive conditions. The most favorable conditions for fast rates of oil production would be to maintain pressures above solution pressures, so that no gas would evolve and there would be no counter flow of gas and oil and the gas movement of the expanding gas cap would be downward with the oil. As long as gas is evolving (in excess of insular conditions), the actual gas movement in the sand pores immediately above the gas-oil contact will be updip, even though the gas-cap area is increasing.

Impression of Superior Gas Pressure in a Gravity-drive Reservoir

The injection of gas into the crestal area of a reservoir at greater than existing solution pressure can take place at any stage of depletion of the pool. It can be applied early to maintain pressures equal to or even in excess of original pressures or it can be applied after all the gas has been blown off or at any intermediate degree of depletion.

In a reservoir with conditions favorable for gravity drainage, the blowing off of the gas will leave a low-pressure gas cap with a rim of dead oil. Unless there is encroaching edge water, the only force left to move the oil through the reservoir rock after the gas energy has been spent will be the head of the oil column itself, and often this may exert only a few pounds of hydrostatic pressure. The impression of gas pressure upon the top of the free surface of the dead oil will augment the hydrostatic pressure, raise fluid levels in the wells and enable them to be produced at faster rates. It will also result in reduced lifting expense and increased present worth of the reserves, but it is doubtful whether ultimate recovery can be materially increased except incidentally by reason of economic benefits. On the other hand, dispersed gas-drive conditions can be developed and recovery reduced thereby, if the pressure and production operations are not carefully conducted.

Building up pressures by injecting gas into the upper portions of a partly depleted reservoir in which freed gas is dispersed in the partly saturated oil sand would cause the dispersed gas to be compressed and some of it to be redissolved. The result would be a tendency to collapse the insular and funicular-like conditions and to facilitate the segregation of free gas and oil and the draining of oil downdip. However, the oil production would have to be regulated to prevent the development of gas-drive conditions. In such a pool, it will be found that there is a maximum rate at which oil can be taken from the reservoir; that care must be taken to withdraw oil uniformly along the front and that wells close to the oil front must be restricted, else gas will finger down to them. Carefully applied, it would appear that gas-drive conditions can be changed into effective gravity drives in some pools.

Choice of Pressures for Gravity Drainage

In a reservoir favorable to gravity drainage, the operator will have a choice of four methods of putting gravity drainage into effect:

1. Maintain a pressure equal to or greater than original solution pressure.

2. Restore or partly restore gas pressure after partial depletion of pressure.

3. Let the pressures be reduced gradually, so that the gas and oil can segregate continuously by counterflow.

4. Produce the field in two stages, first under gas-drive conditions until the gas has been practically eliminated, then by gravity drainage.

The last two methods can be used only where edge water encroaches slowly or not at all. If edge water does encroach strongly, it would be necessary to maintain a gas pressure equal to edge-water pressure to prevent or retard the water from entering the reservoir, which involves a choice between edge water and gravity as to which would be the more effective and profitable agent. Where edge water is not so active, there will be a choice between the four methods.

The choice of gravity-drainage methods should be made by comparing the over-all benefits that may be obtained from them. In some reservoirs, at least, the differences in ultimate oil recoveries will be minor, this statement being predicated upon the small percentage of oil that is left in the pendular region in some uniform sands; as, for example, in the Wilcox sand of Oklahoma City, which leaves little margin for improvement. Where such high depletions can be gained by blowing off the gas, letting the field go through a gas-drive stage and removing the solution gas before gravity drainage starts, justification for high-pressure gravity drainage would have to be mainly on other bases, such as saving gas and gas pressure and reduction in wells to be drilled and in lifting expense.

But few reservoirs have such favorable conditions. In reservoirs where the sand pores are not so large, the dips not so steep and the sand not so uniform, it cannot safely be assumed that there would be no more difference in ultimate recovery between high-pressure and low-pressure gravity drainage than would be expected from the experience in the Wilcox sand at Oklahoma City. It would appear that where capillarity is a stronger force, segregation and drainage cannot begin until lower gas velocities have been reached, and it may be questioned whether, once dispersed, the oil could be drained downdip into an effective front within commercial time limits. It would appear that the less favorable are the natural conditions, the more favorable would have to be the operating conditions, which would be slow oil-production rates together with the maintenance of pressure to retard or even to prevent the evolution of gas. However, the maintenance of pressure in a producing section consisting of strata of sand of varying capillary properties creates a difficult operating problem, as may be seen from the actual case referred to in this article; hence, the answer might be different for a uniform, tight sand than for a multiple zone of variable tight sands.

Judging from available information, best results can be expected by maintaining pressures and controlling production rates.

As the gas can always be bled off later, it would appear to be the forehanded policy to use high-pressure methods for gravity drainage, judging the degree of pressure upon local conditions, such as holding back edge water, the capillary force of the sand, irregularities, the market for gas, the cost of boosting the gas. If later it were found advantageous to bleed off the gas, this could be done.

Though maintenance of gas pressure has been practiced in many fields, it has not always been applied with a full understanding of these principles, therefore the results so far obtained are not to be considered as a full measure of the potentialities of gravity-drainage principles. It has largely been conducted so far on the theory of making gas drives more effective by maintaining the fluidity of the oil and by supplying more gas for gas-drive purposes. The writer believes the primary purpose should be to prevent gas-drive conditions and to induce effective gravity drainage wherever reservoir conditions permit.

USE AND SIGNIFICANCE OF GAS-OIL RATIOS

The use of the ratio of gas to oil production was first proposed as a measure of the efficiency of recovery methods in connection with the gas-drive conditions that prevailed in most of the fields that were being operated at an earlier date. Since the natural supply of gas energy in each pool was limited in amount, the ultimate natural recovery of oil depended upon the efficiency with which this limited supply of energy was used. It was logical, therefore, to reason that a method that would produce a barrel of oil with a smaller quantity of gas would leave more gas in the reservoir to expel more of the remaining oil and, hence, result in greater ultimate recovery.

It is obvious that in pools where water drive or gravity drainage is relied upon to expel the oil, and in which the mechanical use of the gas energy underlying gas-drive conditions more often tends to obstruct rather than to aid in oil recovery, gas-oil ratios would have quite a different significance. In such pools, gas-oil ratios are useful to show the degree to which the gas energy is not used, which, by negation, indicates the degree and effectiveness with which either of the other two energies is being used.

Gas-oil ratios, therefore, can be used as a guide to give some idea of whether gravity drainage is taking place and, if so, whether it is taking place effectively. The ratios can also be used in telling at what rates the wells should be produced and from which wells production should be taken. In general, the oil should be produced from wells low on the flank of the structure and crestal wells should not be produced. Also, in general, the wells with the lowest gas-oil ratios should be produced and the wells with the highest gas-oil ratios should be shut in, but it does not appear necessary under some practical conditions to carry these general principles to extremes, unless a field originally has a gas cap, or unless gas is to be injected from the beginning. At first, some oil could be produced from the crestal area, particularly if the oil were undersaturated with gas. It has been brought out that apparently gas-drive conditions do not develop until enough gas has been evolved from solution to fill the pores more than approximately 10 per cent with freed gas. Until that gas saturation has been reached, the oil moves under fluid expansion and hydraulic flow; so, theoretically, some 10 per cent of the original reservoir liquid could be extracted before gas-drive conditions begin. Segregation of gas from oil could not begin at an effective rate until the gas saturation had reached higher values and the funicular stage had been reached in some part of the reservoir.

The next question is whether production should be limited to the wells farthest downdip, or whether some production could be taken also from other wells below the gas-oil front but not so far down the flanks. The most important factor with respect to the production of the wells is that the total oil taken from the reservoir does not exceed the rate at which the oil can drain effectively downdip in the capillary zone above the gas-oil front. The second most important factor is that the production be taken uniformly around the structure (but making allowances for local differences in dip and sand conditions) so that there would not be created low-pressure areas that would tend to break up the gas-oil front. The limiting rates of oil production will be affected by the degree of pressure maintained. Under gravity-drive conditions, oil can flow laterally along the strike of the sands to level up the front, but necessarily the rate will be rather slow, for the direction of maximum force will be directly downdip. For the same reason, oil can flow between wells just as water can flow between wells in a water sand to reach to the wells beyond, as shown by King, Slichter, Muskat and others. There appears to be no reason why oil cannot be produced from any well below the gas-oil front provided it is not too close to the gas-oil front, and as long as high gas-oil ratios do not indicate that the gas cap is fingering down to the well or that dispersed gas-drive conditions are developing.

Under gas-drive conditions, the gas-oil ratios of a well tend to increase steadily and reach a maximum after most of the ultimate recovery of the well has been obtained, after which they decline again. Under effective gravity drainage, the gas-oil ratios of a well may increase slowly to above solution ratios but when the gas-oil front has reached the well, there will be a rapid increase, especially in thin, steeply dipping sands. Where the gas-oil ratios do increase suddenly from comparatively low ratios, there is reason to believe that there is an expanding gas cap and that the sand is under gravity conditions and a gas-oil front has reached the well.

If the sand conditions were uniform, this abrupt or rapid increase in gas-oil ratios would be a quite reliable indicator but in nonuniform sand bodies there will be several gas-oil fronts, which will reach the well at different times, and it will then be much more difficult to tell whether a front has reached the well or the increase denotes gas drive.

The foregoing discussion has been addressed to the premise that it was desired to effect gravity drainage under high pressures. If it were desired first to blow off the gas and later to conduct gravity drainage under low pressure, the procedures would be quite different. If it were desired to denude the oil of gas as rapidly as possible, the crestal wells and the wells with highest gas-oil ratios would be produced preferentially and the field would be produced as rapidly as possible. In other words, the field would be operated during the gas-drive stage in what would be generally considered the most inefficient manner for the conservation of gas. Ordinarily there would appear to be no justification for such a procedure.

Spacing in Gravity-drainage Pools

The number of wells and the locations of wells needed to secure good recovery must be quite different for the three recovery agents, and attempts to lump spacing into one problem and to find one common solution that will be universally satisfactory will fail, just as it will fail when directed toward protection of property rights. The first step in spacing is to find out into what category the particular reservoir falls.

Under gravity drainage, it will not be necessary to drill more wells than will take oil uniformly from the reservoir perimeter as fast as the oil front can gravitate downdip in the manner described and without creating unsatisfactory local conditions. Except where wells are drilled to blow off the gas, or for gas injection, the wells should be drilled well down the flanks around the low edges of the reservoir. Any well below but not too close to the gas-oil front can be produced until the front reaches it, but updip wells will have shorter lives, smaller ultimate productions, lower hydrostatic pressures and cannot be produced as fast. However, where the sands are not continuous by reason of lensing or faulting, it will be necessary to drill wells to drain each lens and each fault block. Even in reservoirs with regular sands, it will usually be necessary to drill surplus wells in order to distribute production more evenly and to satisfy equities where the field is not unitized.

Field Examples of Gravity Drainage

Four instances of gravity drainage have been selected for illustration. In three fields, the gas was blown off in a gas-drive stage and the oil then drained downdip under low pressure. In the fourth instance, gravity drainage took place under partly maintained pressures. Two of the instances are from literature, though the writer has some personal knowledge of each of them. The other two have come from the personal experience of the writer, but unfortunately he is not at liberty to identify the pools nor to give full particulars.

The first instance is a domal field with moderately high dips. The sands are coarse, of moderate porosity but of high permeability, the oil is light and originally was nearly saturated with gas but there was no original gas cap and edge-water encroachment has been relatively unimportant.

The first wells were drilled near the crest of the structure and operations were conducted in the old manner, the wells flowing at nearly full capacity. The wells at first behaved in the usual manner for a dissolved gas-drive field (Fig. 6). Production declined on the usual 63° slope when plotted on log-log paper, but within barely two years the production-decline slopes of the crestal wells abruptly steepened to about 80°, and in two or three years more declined to uneconomic rates. Wells lower on the structure were drilled later and behaved quite differently. Those halfway down the flank came in at lower initials and declined slowly at less than a 45° slope, but in a few years they too abruptly changed trend to a steep slope of about 80° and within two or three years thereafter declined to uneconomic rates. Wells low on the flanks, which were completed still later, came in at still lower initial productions but have since

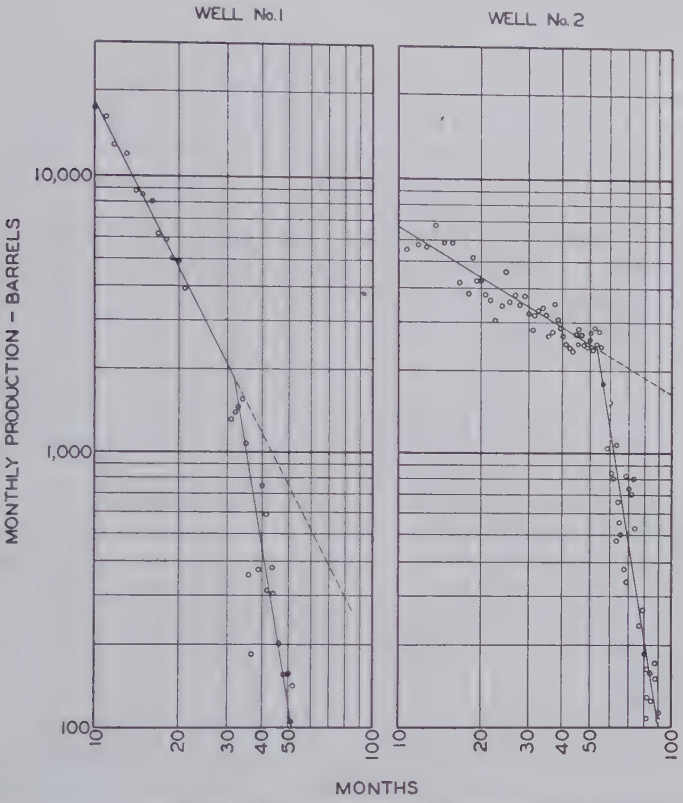

FIG. 6.—PRODUCTION-DECLINE CURVES SHOWING GRAVITY DRAINAGE TOWARD AND AWAY FROM WELLS.

held their productions with little or no decline. Today there is a circle of producing wells around the edge of the pool with no interior wells producing.

This field, older and smaller than Oklahoma City, has had a similar experience. Early in its life, the gas was blown off through the crestal wells and within two years the gas and oil started to segregate and to form a low-pressure secondary gas cap in depleted sand updip, while the oil gravitated down the flank to resaturate the sand with nearly dead oil, in a manner similar to curve 2 in Fig. 5. The gas cap did not form first exactly at the apex of the structure but a little to one side and under an undrilled location and later was discovered when the location was drilled. Still later, another local gas cap was formed rather low on the plunge of the fold, but these two local gas caps soon merged into the main gas cap. The field passed through a transition stage from gas-drive to gravity drainage, lasting nearly four years.

The change in the curve trends mentioned above and shown in Fig. 6 are explained as follows: In well No. 1, which was near the crest, the change from the 63° to 80° slope occurred when the gas drive collapsed and oil started to gravitate away from the well. Well No. 2, midway down the flank, was completed just after gravity drainage began, and for nearly four years oil was draining toward it, after which the oil front passed it and oil was then draining away from it.

The recession of the gas-oil front downdip has been quite regular and has nearly followed contours. Wells have successively and abruptly lost oil production and gone to gas while the low-pressure gas cap has progressively enlarged.

Lakeview Pool, California

The Lakeview pool is on the north flank of the Thirty Five anticline in the Sunset-Midway district of Kern County, California. The geology and early history are described by Pack[6] and the occurrence of gravity drainage is described by Sanders,[7] who is freely quoted.

The famous Lakeview gusher, which opened the pool, came in on March 10, 1910. In a few days it got out of control and flowed wild for 544 days, during that period reaching rates of 65,000 bbl. daily. Some 8,250,000 bbl. was produced. After the well ceased flowing, it was cleaned out, but it flowed thereafter for only a short time and efforts to make it pump failed. Sanders says: "The reason for this condition was not known but in view of present knowledge it seems quite certain that the fluid level had receded downdip to leave the bottom of the famous well in a zone of low-pressure gas."

The discovery of the Lakeview gusher was followed by a frenzied drilling boom but the results were disappointing. Some wells updip found little or no sand and wells downdip found oil sand that would produce only low-pressure gas. "This condition led ultimately to the conclusion that the gusher had exhausted its producing sand."

Later it was determined that the Lakeview sand was one of a series of buttress sands along the north flank of the Thirty Five Hill anticline. In 1919, two wells drilled into the gusher sand would not flow but pumped at phenomenally steady rates. At the time it was not known that the wells had been completed into the Lakeview sand, nor was it understood why gas was lacking in this sand and why production held up so steadily.

Beginning in 1934, Fay L. Wright, and later W. E. Dunlap, made detailed studies of the area, which led to the discovery of the true conditions, and by June 1939, 88 wells had been drilled to the Lakeview gusher sand, of which 78 were producing. It was found that structurally high wells produced only low-pressure gas and structurally low wells produced a mixture of oil and water, but wells in between were good pumpers, one well having had an initial production of 800 bbl. daily. The oil was 22°A.P.I. and it was accompanied by very little gas. This productive zone was from ⅛ to ¼ mile wide and extended 2 miles along the strike. The dip was 20°, the sand zone "feathered out" updip but reached a maximum productive thickness of 200 ft. just above the water level. The Lakeview sand is divided into three distinct "fingers" by shale breaks.

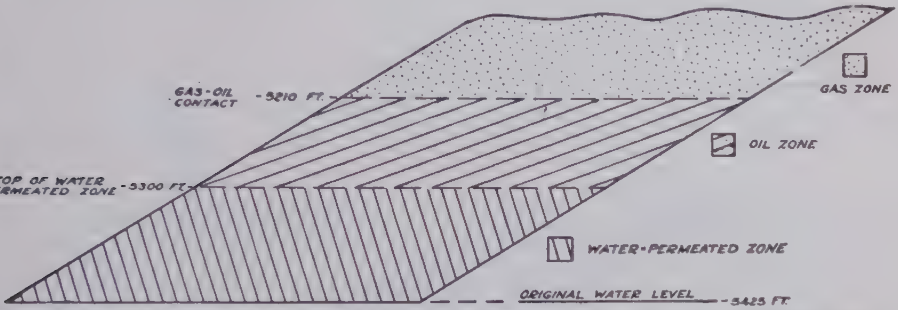
GAS-OIL CONTACT -5210 FT.
TOP OF WATER PERMEATED ZONE -5300 FT.
ORIGINAL WATER LEVEL -5425 FT.
GAS ZONE
OIL ZONE
WATER-PERMEATED ZONE

Fig. 7.—Division of reservoir into gas, oil and water-permeated zones in the Wilcox sand of Oklahoma pool. (*Katz.*[3])

It was soon discovered that the oil level dropped regularly and that updip wells would lose production and then go to low-pressure gas. It was also observed that edge water was nearly stationary. These facts led to a correct diagnosis of conditions. In 1919, the oil level was known to be at about minus 1200 ft.; in January 1935, it was at minus 1600 ft., and in February 1938, it was down to minus 1924 ft. The estimated rate of drawdown in 1938 was 12.8 ft. per month, or 5 in. per day, and "so regular is this recession that the drop in the fluid level may be determined by the volume of the oil withdrawn, just as in a tank. For every 51,000 bbl. of oil pumped from the reservoir, the fluid level is now lowered one foot. With this knowledge, the calculation of reserves in the pool has become simple and accurate."

The Lakeview sand to the date of Sanders' article had produced a total 12,000,000 bbl. under gravity-drainage conditions, and the future production was estimated at 7,000,000 bbl.; thus the ultimate estimated recovery is 27,250,000 bbl., of which 30 per cent was by gas drive and 70 per cent will be by gravity drainage.

One well near the top blew off all the gas from a reservoir 2 miles long, containing 27,250,000 bbl. of recoverable oil, and the oil front then leveled or nearly leveled off and receded uniformly downdip; a year later, oil was withdrawn from downflank wells. There is no information on the transition stage except that as soon as the gas pressure would no longer lift the oil into the Lakeview well, the oil drained away from the sand at the bottom of the hole and there was no oil there to be pumped.

Oklahoma City Pool

The gravity drainage in the Wilcox sand in the Oklahoma City pool has been described by Katz,[3] and the geologic conditions of the history of the pool have been described in many other earlier articles.

The development of gravity drainage in Oklahoma City has been quite similar to that in the field first described. The Oklahoma City pool was drilled first along its upper margins, where there appear to have been several small original gas caps. Though the Wilcox sand production was curtailed to some extent, the gas was rapidly blown off and reservoir pressures were rapidly reduced. Evidence of the segregation of gas from oil and gravity drainage appeared quite early. Fluid levels became low and migrating gas caps were reported. Because of the great extent of the Wilcox pool and the delayed development of the northern portion, the development of gravity drainage began at different times in different parts of the pool.

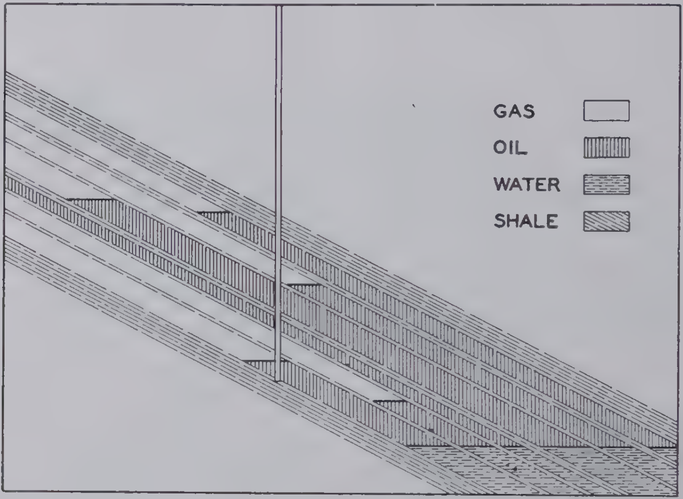

FIG. 8.—SEGREGATION OF GAS FROM OIL IN A MULTIPLE SAND SECTION.

Judging from the curve reported by H. C. Miller[1] (see Fig. 5), the segregation of gas and development of gravity drainage began to be important in 1934, when the average pressure became less than 750 lb., and was virtually complete by 1936, when the average pressure had dropped to 50 lb. This period of some two years is judged to be the transition period, and since that time recovery has been under gravity drive, as described by Katz. However, during this same period, edge water advanced for a time and then stopped. The present conditions are shown in Fig. 8.

The Wilcox sand is very permeable, the oil is of low viscosity and dips are up to 15°, hence conditions are favorable for gravity segregation.

The writer doubts whether gas repressuring would materially help ultimate recovery but the building up of the gas pressure above the gas-oil interface should enable the oil to be recovered at a faster rate and at cheaper production expense. In another pool, gas injected into the gravity-drained secondary gas cap did not cause the wells there to produce again but it did increase the productive rates of wells located below the gas-oil front.

GRAVITY DRAINAGE IN A FIELD WITH IRREGULAR SANDS

The fourth example of gravity segregation and drainage occurred in a part of a field where the sands had dips of 30°. The wells produced from a multiple zone of alternating sands and shales several hundred feet thick. The zone was divided into five to eight sand bodies and each sand body was split by shale partings. There was considerable irregularity in the producing section, both along the bedding and between beds. The sand varied from medium to fine in grain size and was poorly cemented. The slow build-up of pressures and the large differences in bottom-hole pressure between near-by wells showed much impedance, due partly to low permeability and partly to lateral irregularities. The oil was originally undersaturated with gas but had average viscosity. The wells were produced under high back pressure through small chokes, and pressures declined slowly. The wells downdip maintained low gas-oil ratio for many months but those updip developed increasing gas-oil ratios early. Bottom-hole pressures are still more than half the original solution pressure. There was no evidence of an original gas cap and edge water has encroached only slightly.

Because of irregularities in structure and bedding, the conditions are complicated in detail, but the important conditions that affect the development of gravity drainage are given.

After the wells had produced for a few years, even the wells low on the structure began to develop high gas-oil ratios. It was suspected that gravity segregation and drainage were going on, so when two new wells were to be drilled down to deeper sands occasion was taken to test out conditions in this upper zone.

The two wells were drilled about 1000 ft. apart and nearly on strike. Between was an old well in the upper sand, which had produced at solution gas-oil ratios for some months after completion but recently had built up to gas-oil ratios more than five times the solution ratio. In the new wells, the producing section was cemented off and then each sand body was shot out and tested separately. Various conditions were disclosed. Some of the sands would produce gas only, some had high and others had moderate gas-oil ratios while some sands produced at nearly solution ratios. There was no systematic relationship to relative depth, as gas was found both above and below sands with low gas-oil ratios. The conditions are illustrated diagrammatically in Fig. 8.

It was concluded that segregation had taken place but, owing to irregularities, at a different rate in each sand member; in some, the gas-oil front had already receded downdip past the wells and the sand would produce only gas; in other sands, the oil front had not reached the well and the sand would still produce at low gas-oil ratios; in still other sands, either the front was near the well or, owing to variations within the sand member, it had several minor fronts and the well produced oil but at a high gas-oil ratio.

From the production histories of the other wells in the area, it was evident that the oil was draining downdip, but quite irregularly, as was to be expected where so many sands were being produced together through each well, and where there was so much irregularity both between sand members and along the bedding of each sand member.

Repressuring a Gravity-drained Reservoir

In one field, which had had a history similar to the first three examples, gas was injected later from another source into the drained crestal area after the original gas had been depleted to nearly atmospheric pressure. Forcing gas through the sand of the gravity-drained area led to no commercial production but built up the gas pressures; the fluid levels and the potentials of the wells below the gas-oil contact increased by several times and the daily rate of production was increased correspondingly. The result of this repressuring was to speed up recovery and reduce lifting expenses of the oil remaining down the flanks.

Making a Choice between Recovery Agents

Since natural conditions often permit choice between the three recovery agents by preferential use of one and repression of the other two, careful studies should be made of the conditions that will permit such choice, and the comparative advantages of the three methods under different natural and economic conditions. Such a study should include comparisons of ultimate oil recoveries, rates of recovery developing costs, operating expenses and conservation of gas.

Though high ultimate recoveries can be secured by continued secondary gas drive in the laboratories, equalling in some experiments water and gravity drives, much of the recovery is under conditions that would be uneconomic in the field, and it is generally admitted that under field conditions, dissolved and dispersed gas drive almost always results in lowest economic recovery, and that it should be used only where other agents are not effective or where its use is justified by some economic advantages. There are many fields where, because of low dips and tight sands, neither edge water nor gravity is effective and either gas drive or artificial water-flooding must be employed. Economic conditions will largely determine which should be used and whether the field should first be produced under natural gas drive before artificial gas drive or water drive should be applied. It is to such fields that secondary-recovery methods are most applicable.

There are other pools that are favorable for gravity drainage but into which edge water will encroach not at all or only to a limited distance. In many pools, edge water encroaches so slowly that either it is brought to a stop by edge wells pumping out the water as fast as it enters the reservoir or it encroaches more slowly than oil can drain downdip. In still others, there is a limited water supply and encroachment soon ceases. Under some conditions, it is possible for edge-water drive to go on around the lower edge of the pool and at the same time gravity drainage can be going on updip, the two working toward each other.

As a rule, reservoirs into which edge water can encroach rapidly and finally flood the reservoir completely have natural conditions within the oil-bearing portion of the reservoir that are favorable for gravity drainage, but it would be necessary to hold back the edge water by injecting gas from other sources in order to maintain a gas pressure greater than edge-water pressure if encroachment were to be blocked completely and gravity drainage permitted to become the sole effective recovery agent.

Since usually there will be such a choice wherever edge-water drive can be made effective, it is important to determine under what conditions gravity drainage would be preferable. Until recently, there was a preconception that edge-water drive was the most efficient agent possible, but the writer doubts whether there is enough information available to warrant such a conclusion at this time. So far, the favorable opinion on the effectiveness of water drive has been formed from comparisons with dissolved gas drive but gas drives occur in fields where recovery conditions are least favorable, whereas the comparison should be made between edge-water drive and gravity drainage. Until there is a proper basis for comparison between edge-water drive and gravity drainage under comparable conditions, conclusions should be reserved. From the little information available to the writer, he suspects that, under some conditions at least, higher and more profitable recoveries are possible by gravity drainage. The bases for this belief are partly presented.

Experiments on tubes of sand (atmospheric moisture not removed) showed that after drainage water could be passed upward through the depleted sand without displacing any oil, hence it would appear that drainage can remove at least as much oil as water displacement under such conditions.

When oil is displaced from sand by a rising column of water, a certain percentage is displaced water free, after which oil and water are produced together. In the field, production has to cease because of high lifting costs as water increases. Even in a uniform sand, production would have to be stopped before maximum displacement has been reached. On the other hand, oil lagging behind in a gravity-drainage system can reach lower wells and the economic limit would be determined by low oil-production rates rather than by high water rates. It would appear probable that there would be less loss by this lagging, and hence higher commercial recovery, in a uniform sand under gravity drainage than under water displacement.

Nonuniform sands cause much trouble in both edge-water drive and gravity drainage (Fig. 8). In both, the oil fronts in the several sand members will advance fastest in some one of the several sand members. When a water front reaches a well, much water must be pumped with the oil, or the well plugged or the sand member located and cemented off. These irregularities will also cause entrapment of bodies of oil by the water, so that recoveries will be much less than shown by laboratory tests in uniform sands.

In the same irregular sand body, the oil would drain downdip fastest in the sand member through which water would invade fastest. When the oil front in this member passed a well, the well would produce at a high gas-oil ratio, and to maintain pressure there would be an increased expense for raising the gas back to injection pressure. The operator would be confronted with the alternative of: (1) continuing the expense of boosting the gas back to injection pressure, (2) shutting in the well, (3) plugging it or (4) locating the gassy sand member and sealing it off. There would, however, not be so much danger of entrapping bodies of oil that could not afterward be recovered. After the lowest wells had become too gassy, it might still be feasible to drill wells that would exclude all but the sand members that still were saturated with oil. The desirability of completing wells in such manner that the sands composing the produced section can be isolated if needed is quite evident.

This reasoning is supported by the finding by Katz in the Oklahoma City pool, where he reports that the sands above the gas-oil front were more completely denuded of oil than the oil sands into which edge water had advanced; also, that laboratory tests favored gravity drainage over water displacement. However, Oklahoma City may be a special case, as the sands originally were nearly lacking in connate water and conditions were exceptionally favorable for gravity drainage.

CONCLUSIONS

Gravity is an everpresent force in oil fields that will drain oil from the reservoir rock from higher to lower levels wherever it is not overcome by encroaching edge water or expanding gas. Gravity has always been recognized as one of the three main recovery agents but generally it has been dismissed as relatively unimportant, consequently study of it has been neglected.

Field evidence shows that in some reservoirs gravity has been effective and has resulted in recoveries equal to or perhaps exceeding what could be expected from water displacement. So far, effective gravity drainage appears to have been mostly unpremeditated and with little or no foreknowledge of the conditions and manner of operations most favorable for it. A study of the principles will disclose that gravity drainage can be applied more effectively and to more reservoirs than has accidentally occurred until now. These principles will apply particularly to the effectiveness of pressure maintenance by means of gas. In some field, the operator will have the option of using either naturally encroaching edge water or gravity drainage in conjunction with maintenance of gas pressure, therefore it is important to determine which is the more effective under a given set of conditions. At this time we do not know what proportion of our oil fields could be benefited by the application of gravity-drainage principles.

Further investigations of gravity drainage are needed to round out our knowledge of the performances of oil reservoirs. This will involve further laboratory and theoretical investigations coupled with a survey of field conditions to determine where, to what extent and under what conditions gravity drainage has been important or could be made effective. It is urged that the members of this organization reexamine the fields with which they are familiar and publish any evidences of gravity drainage to the end that such information can be compiled and analyzed and the results be made known to the industry. As the behaviors of wells under water encroachment and gravity drainage may be similar until either water or gas reaches the well, pools supposed to be favorable for edge-water drive should be reconsidered to determine whether in fact edge water is the dominant agent.

Acknowledgments

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Acknowledgement is also given to Mr. L. V. Fees, who some years ago called the writer's attention to a striking instance of gravity drainage.

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The Role of Capillarity in Oil Production

By G. L. Hassler,* E. Brunner* and T. J. Deahl*

(Austin Meeting, October 1942)

Abstract

The capillary effects in reservoir rock are discussed in terms of the pressures they cause in sandstones and dolomites. Data for the two-phase case (oil-gas or water-gas) and for the three-phase case (oil, water and gas in rock) are used to demonstrate that in one sense the wetting preference of a rock depends on its saturation. The nature of capillary hysteresis is described for partially stable conditions, and the concept is enlarged. Reproducibly measurable pressures include the "capillary pressure," which is the pressure difference between any two phases that are each interconnected; the "threshold pressure," necessary to force a nonwetting phase through partially saturated rock; the "displacement pressure," which is that special case of the threshold pressure in which both phases fully saturate separate portions of the rock. Displacement pressure is equal to the minimum value of the "capillary pressure."

The theory of flow including capillary forces is developed at the producing surface of a well to reveal the presence there of a pressure discontinuity in the gas (or other nonwetting) phase that can be controlled to the end that more oil may be produced from an oil field. Experiments with packed sand-flow tubes having artificial producing surfaces support the theory.

Introduction

The basic surface quantities acting in an oil field are two: namely, surface tensions and contact angles. These are the quantities, variously expressed, and particularized as spreading forces, adhesion tensions, heats of wetting, etc., which are measured in the laboratory by techniques mostly confined to flat or circularly cylindrical surfaces. Such measurements have not had the extensive engineering application they seem to deserve because in most practical cases they are unavoidably compounded with the complex and unapproached subject of the internal shape of the interstices of rock.

In this paper it is intended that the pressure differences developed in rock by capillarity be examined, defined, and given some engineering use in terms of some new measurements that have been made. Such pressure differences—namely, the capillary pressure, the displacement pressure and the threshold pressure—seem to provide a proper contact between the basic molecular quantities and the oil field.

While certain modifications of usage will be undertaken, the present effort rests upon the background of work by the U. S. Geological Survey,[1] by Versluys,[2] and especially by W. O. Smith,[3,4,5] which has been reviewed recently in papers by Leverett.[6,7]

The most important concept of pressure difference is the *capillary pressure*, a function of saturation that expresses the pressure difference between the interconnected phases in a rock. It is often measured when water and air are the fluids present, but it can be measured with other fluids. A number of curves of capillary pressure have recently been measured by a method which it is intended shall be published in a later paper. Since heretofore capillary-pressure measurements upon rock have not been

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[1] References are at the end of the paper.

available, these new measurements are presented here to facilitate discussion.

Two-phase Capillary-pressure Measurements

Fig. 1 presents a group of curves that were obtained with argillaceous, soft sandstone from an oil field in California. Fig. 2 shows data from cavernous dolomitic core samples drilled from a field in Texas. Fig. 3 describes a miscellaneous group of sandstones from Mid-Continent fields. The ordinates, expressed in atmospheres to conform with the Darcy system of units, give the pressure difference that occurs across the interface between water and air in the core when the core is first saturated with water and then progressively desaturated. The curves do not show any points because the procedure used in obtaining them does not measure directly either the saturation or the capillary pressure. For this reason it is difficult to estimate error. However, it is likely that the error includes the usual 2 or 3 per cent uncertainty of saturation and about 5 per cent probable error in the pressure.

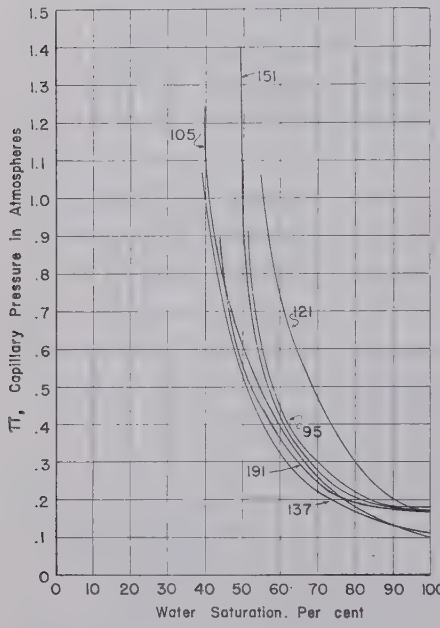

FIG. 1.—CAPILLARY-PRESSURE CURVES OF SANDSTONES FROM A CALIFORNIA FIELD.

Permeability plugs of one centimeter radius (extracted with benzene) were used with water. The figures give the permeability in millidarcys of the respective samples.

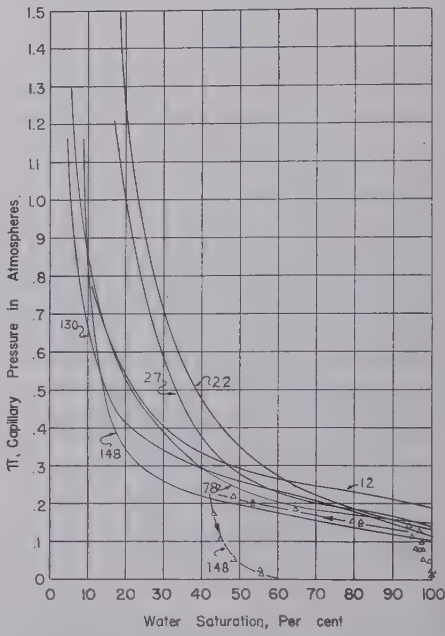

FIG. 2.—CAPILLARY-PRESSURE CURVES OF DOLOMITIC LIMESTONE SPECIMENS FROM A TEXAS FIELD.

The specimens were somewhat cavernous but with very few holes larger than one millimeter. Permeability plugs (benzene extracted) were measured with water. The figures give the permeability in millidarcys.

In the single case of the 148-millidarcy dolomite, Fig. 2 shows a set of points obtained by another less accurate method of measurement, which is adapted to the observation of the lower (absorption) branch. In this less accurate procedure, the points of the upper branch give the pressure necessary to withdraw water from the artificially saturated core. At saturation 0.42 the process was reversed, and the pressure exerted by the core in sucking the oil back into the core was measured. A wait of about 15 min. was involved at every point, to establish reasonably valid equilibrium.

The upper branch is reproducible, but the lower (absorption) branch is instead one of a family of curves, each member being farther to the left in accordance with the degree of desaturation reached before the process is reversed. Furthermore, the exact value obtained seems to be fortuitous in other respects.

An average curve of capillary pressure for a group of reasonably hard representative Mid-Continent sandstones could be represented by the formula

$$\sqrt{k}\,\pi = 2.53\left(\frac{1-s}{s}\right)^{\left(0.52\frac{1-s}{s}-0.25\right)}$$

where k represents the permeability in millidarcys, s is the saturation expressed as a proper fraction, and π is the capillary pressure in atmospheres, measured with water and air as the fluids in the rock. While this formula occasionally may be used for guesswork based on permeabilities, it must be emphasized that the capillary-pressure curves of sandstones even of the same permeability differ greatly from each other both in respect to magnitude and shape, as can be seen by inspecting the data of Figs. 1, 2 and 3. No systematic variation with porosity has been found in rock.

The shape and position of these capillary-pressure curves have to do primarily with the distribution of pore sizes in the rock and partly also with the contact angle.[8] At full saturation a certain threshold pressure exists, which measures the curvature of the flattest surface that can exist within the largest effective pore. As the saturation is reduced, gas penetrates smaller and smaller pores and more deeply into rock angles at points or lines of grain contact, until a low saturation is reached where very high curvatures are encountered, so high that the two-phase capillary-pressure curve seems in its vertical rise to approach an irreducible saturation asymptotically. The threshold pressure first mentioned is believed to be the equivalent of the "displacement pressure"[8] as previously defined for porous materials, while the irreducible saturation corresponds to the "wilting point" of soils.*

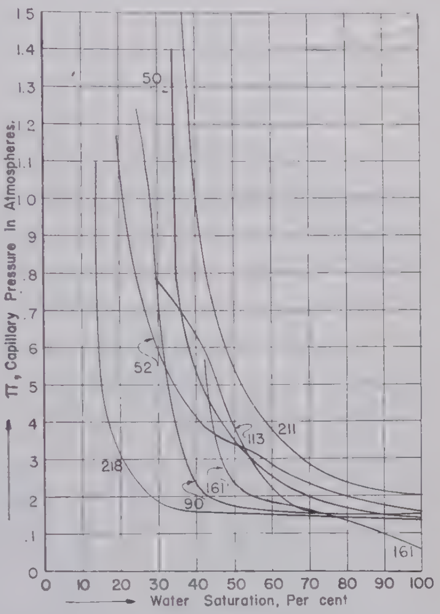

FIG. 3.—CAPILLARY-PRESSURE CURVES OF MISCELLANEOUS MID-CONTINENT OIL-FIELD SANDSTONE.

Permeability plugs (benzene extracted) were measured with water. The figures give the permeability in millidarcys.

In most cases the irreducible saturation measures the pore space of the clay content.

CAPILLARY PRESSURE AT CRITICAL SATURATIONS

A common feature of well-sorted sandstones, such as the 218-millidarcy core of Fig. 3, is the almost horizontal "seat" extending to the left from 100 per cent saturation (where the ordinate represents the displacement pressure) over a wide range of decreasing saturation. For example, in the case of the 218-millidarcy core of Fig. 3, one may conclude that the pores were so uniform and so well rounded that after the air broke through the outer surface with a radius of curvature of 11 microns (obtained by dividing twice the surface tension by the pressure), a reduction in radius of curvature to only 9 microns enables 60 per cent of all the pore space to be swept clear of water. At 15 per cent, however, the advancing heads of air-water meniscuses began to encounter the filling of clay, so that little more water could be forced out of the core even though the radius of curvature was made less than one micron.

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* The "wilting point" seems to be the saturation that corresponds to about 16 atmospheres, or 480 ft. of water, which is the limit of the suction capacity of plant material.

THREE-PHASE CAPILLARY-PRESSURE MEASUREMENTS

Fig. 4 presents a set of measurements for the capillary pressure (suction) of oil at enough proportions of oil, water and gas to permit extrapolation of this interesting quantity over most of the ternary diagram The oil data refer to a piece of fine-grained, well-cemented sandstone having a permeability of 87 millidarcys. In these measurements the saturations and pressures were obtained directly, so that the positions in the diagram (decimal points) and the upright figures described primary data in atmospheres for the capillary-pressure difference between *oil* (kerosene) and *air*. The slanted figures give approximate capillary-pressure difference between *water* and *air* for a different group of similar cores for purposes of rough comparison. The contours of Fig. 4 are drawn to indicate lines of equal suction for oil.

Evidently the water suction is roughly symmetrical with respect to that of the oil, being in excess by the ratio of the air-liquid surface tensions. While the data available are few, it seems likely that where the oil and water used in this test have no preference as to which will be the external phase in an emulsion, the wetting preference of the rock will be revealed by the lack of a reciprocal symmetry in the contour sets of oil and water capillary pressures as plotted in the ternary diagram.

All the data of Fig. 4 represent the desorption branch of the hysteresis loop.

GEOMETRICAL EXPLANATION OR VISUALIZATION OF CAPILLARY PRESSURE

The value of capillary-pressure data lies principally in the fact that capillary pressure is a thermodynamic quantity that does not depend for its usefulness (as a measure of the tendency of liquids to move) upon the truth of any particular physical picture of its origin. Nevertheless, it is worth while to consider carefully the behavior of the interfaces whose curvatures give rise to the capillary pressure, as this behavior is affected by the size, shape, distribution and wetting characteristics of the pore spaces in the rock. Smith[3,4,5] has discussed capillary pressure in some detail from this point of view, his theoretical considerations culminating in an explanation of King's data on the capillary pressure of sand in terms of a model consisting of a pack of equal spheres. This work has recently been reviewed by Leverett.[6]

CAPILLARY HYSTERESIS

A phenomenon that one is led to expect by such a theoretical consideration of capillary phenomena in porous media, and which is in fact verified by experiment, is that of hysteresis. The capillary pressure is not uniquely a function of the saturation but depends also on the previous history of the system. This hysteresis arises from the complex geometry of the porous medium that allows the fluids to be in equilibrium with different distributions and different capillary pressures. The particular distribution that the fluids will assume, and hence the capillary pressure that will obtain, will naturally depend on the immediately preceding distribution. In the various states of distribution considered here it is supposed that both phases are continuous throughout the porous medium. The states are then stable; they represent true equilibrium.

Besides these various possible stable distributions of the fluids, which give rise to what we shall call "optional" hysteresis in the capillary pressure, other distributions are possible in which small globules or bubbles of the nonwetting fluid become separated from the main connected body of fluid and are trapped, either in dead-end interstices or in interstices with only narrow necked openings. The possibility of such entrapment clearly gives rise to further hysteresis in the capillary pressure, which we shall call "trap" hysteresis. While such trapped globules or bubbles may be in equilibrium, or nearly so, when they are first formed the equilibrium is not in general stable. Since the volume of the trapped globule is fixed (except to the extent that it may be compressible), the curvature of the meniscus that separates it from the other fluid cannot change. If the pressure difference between the two fluids (the capillary pressure) is increased, the trapped globule will tend to dissolve and finally emerge after diffusion in the main connected mass of fluid. This process, however, is very slow, so that while fluid

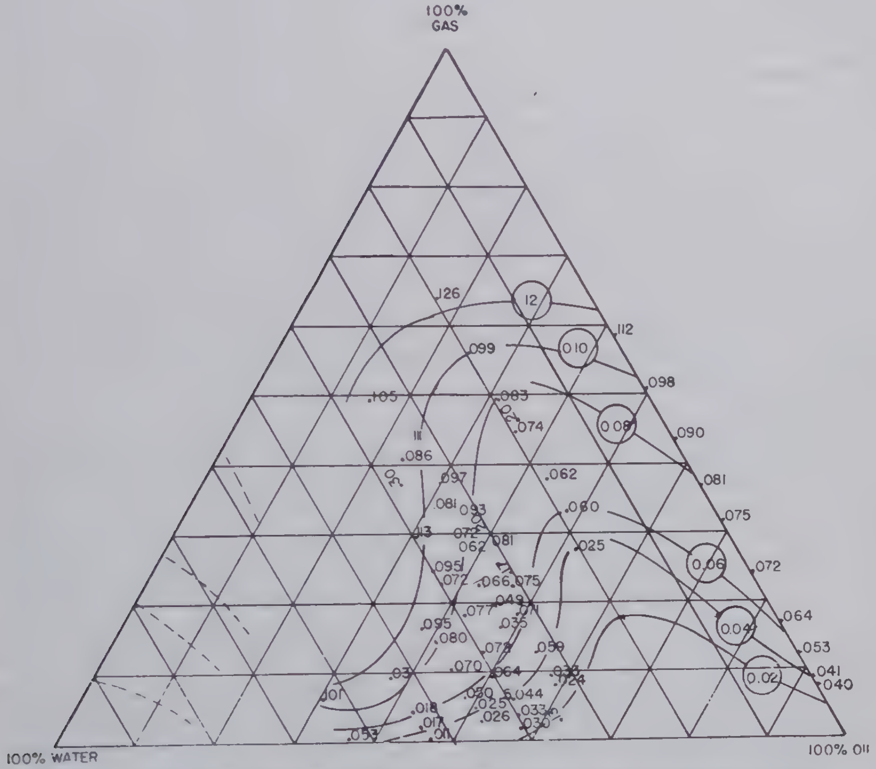

FIG. 4.—TERNARY DIAGRAM OF CAPILLARY SUCTION OF SET SANDSTONE FOR OIL.

A permeability plug of 87 millidarcy sandstone extracted with benzene was measured with water, kerosene and air. The circled figures mark contours of the capillary pressure $\pi_{\text{oil-gas}}$ in atmospheres. The upright figures show the measurement of $\pi_{\text{oil-gas}}$ at the decimal point position.

The inclined figures give the capillary pressure $\pi_{\text{water-gas}}$ for individuals of a different group of virgin (not extracted) sandstone cores.

distribution involving trapped globules or bubbles is not stable, for many purposes it may be regarded as practically so.

When trapped bubbles are present, different bubbles may be bounded by meniscuses with different curvatures, since they are not in equilibrium. In such a case the pressure difference across the boundary of a bubble will be different for different bubbles. Since it is convenient to define capillary pressure as the pressure difference across the interface between the two phases, the trapped bubbles, with their multitude of such pressure differences, introduce a troublesome disunity of thought. Because of this theoretical incoherence, the lack of equilibrium, and its relative nonreproducibility, previous authors[5,6] have chosen to disregard what is here called "trap" hysteresis. Nevertheless the capillary states involving trapped bubbles are relatively stable and apparently are real phenomena in oil-field rocks. Moreover, it now appears that in many oil-field problems, trap hysteresis is a fact that should not be disregarded. The "heading" of flowing wells, the encroachment of oil into a gas cap, and the daily repressuring cycle of intermittently operated gas-drive properties are examples of operating situations where these quasi-stable "trap" hysteresis states are important. In this paper trap hysteresis will therefore be recognized and capillary pressure will be redefined so as to take it into account. Capillary pressure in a porous medium is defined accordingly as the pressure difference that occurs between the mobile interconnected masses of the two fluid phases in question, and it will be associated with the saturation at which it occurs, even though the relation is not altogether permanent. One difference between the previously recognized and presently recommended types of capillary-pressure curves for real material lies in the fact that the lower branch of a hysteresis loop of capillary pressure as now defined may meet the axis at relatively low saturation, as in Fig. 2. As capillary pressure has previously been defined, the measurements would have to be made after such long waits for diffusion equilibrium that the curve would meet the axis only at full saturation.

MEASUREMENTS OF THE WETTING PROPERTIES OF ROCK

The ideas set forth may now be used to examine in detail the "displacement-pressure" measurement of the wetting preference of porous materials as developed by Bartell and Osterhof.[8,9] In this measurement a porous material, generally of a pure, carefully sized substance, such as silica, is held in a containing chamber between two pipes that communicate with the interstitial spaces on opposite sides of the porous material. It is arranged that two immiscible fluids form a surface of contact within the porous material, each fluid communicating with an external manometer through a separate pipe. Generally it will be found, with this apparatus, that a reproducible pressure exists across the surface of contact of the fluids. This pressure is called the "displacement pressure" because it occurs during the displacement of one fluid by the other.

The pressure is directed toward the nonwetting fluid and is said to be proportional to the surface tension and the cosine of the contact angle and inversely proportional to the effective radius of the interstices of the porous material. By the use of preliminary measurements with immiscible fluids of known interfacial tension and contact angle, one can, according to Bartell and Osterhof,[8,9] determine this effective capillary radius of the interstices, and thereafter determine the contact angle of any fluid pair in terms of such constant radius and the measured "displacement pressure." While it seems to us that a correction term may be necessary to take account of the possibility of a dependence of this "effective radius" upon the contact angle, the measurements made in this way are known to give reasonably coherent results.

In this displacement process there can be no plane or moderately curved surface that sharply bounds the two phases. It is known that the flooding process leaves a volume of undisplaced fluid behind the encroachment front of the order of one fifth or more of the whole pore volume. As demonstrated above by the success of Smith in explaining the experiments of King, surface equilibrium within a pack of comminuted solids demands a uniformly curved interface between the two phases. In consequence, no sharp gradation boundary of saturation is stable; in complete equilibrium, the displacement cell would necessarily have a uniform saturation of both fluids except for minor optional hysteresis everywhere within the sample. One is led to inquire which saturation of the curves of Figs. 1, 2, 3, 4 corresponds to the pressure that obtains in the displacement-cell experiment.

Evidently it is the saturation that corresponds to the least capillary pressure, for this is the condition that will first cause movement. The static pressure that can be developed by the meniscus in the largest available interstice is the displacement pressure. This pressure is equivalent to the least static pressure that is sufficient to force the (nonwetting) fluid through a saturated zone of the material, as in driving gas out of a partly saturated rock through a surface that is immersed in water.* It is also equal to the least pressure necessary to drive the fluid into the core when it is completely saturated with a second immiscible fluid that is entirely free to escape.† The "displacement pressure" can thus be measured at a fluid displacement boundary inside the porous specimen, and also at the outside boundary of the specimen either by driving toward or away from the saturated surface provided only that static conditions prevail. As will be further described later, these last two types of measurement have special significance in determining the important "critical" saturation, in the first case, and in determining the effect of the outlet surface on production efficiency in the second. The Bartell-Osterhof cell or internal-boundary procedure[8,9] is of greatest significance in determining the contact angle or wetting preference of pure materials.

The cases similar to those above, but in which definite movement of the gas into and through a fixed saturated zone take place, exhibit a special kind of "dynamic" as opposed to "static" displacement pressure. This pressure probably is as well defined a characteristic of rock as the displacement pressure.

In such cases a characteristic saturation[14] called the critical (or equilibrium) saturation of the rock prevails. But the capillary pressure at the critical saturation can be measured by static experiments. One might suppose that this capillary pressure at the critical saturation is actually the effective "dynamic" displacement pressure, which will be called the critical displacement pressure. The data necessary to prove that this supposition is correct have not yet been obtained. In most cases the difference between capillary pressure at full saturation and capillary pressure at critical saturation is small, and there is a possibility that capillary pressure under dynamic conditions may be so variable as to blanket the distinction.

In order to extend the discussion to the wetting properties of real rock, Fig. 5 is presented. The two curves show the capillary pressure π, as measured for a piece of sandstone having permeability 87 millidarcys.

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* This type of measurement has been described in connection with a method for measuring the size frequency distribution of the interstices of rock.[11]

† This type of measurement has been used in connection with early measurements of relative permeability to gas.[12]

Curve *a* gives the capillary pressure found during slow displacement of water by air. Curve *b* gives the capillary pressure found during slow displacement of kerosene by air. If all the material in the core were wetted in the same way by oil-air as by water-air, the ratio of the capillary pressure measured with kerosene to the capillary pressure measured at the same saturation with water would be equal to the ratio of kerosene-air surface tension to water-air surface tension; namely, 0.41.

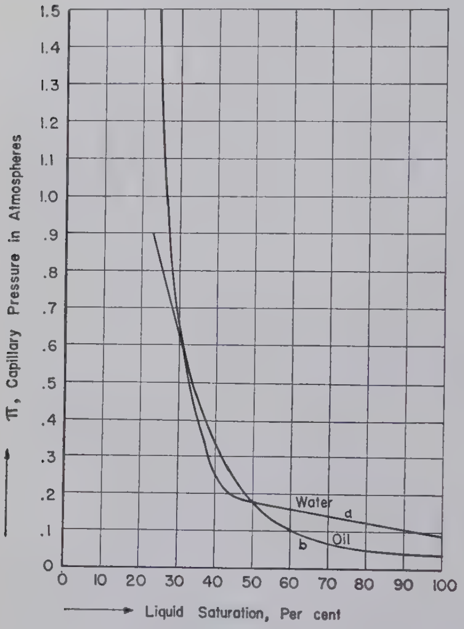

FIG. 5.—CAPILLARY-PRESSURE CURVES OF AN 87-MILLIDARCY SANDSTONE OBTAINED BY DISPLACING WATER WITH AIR AND BY DISPLACING KEROSENE WITH AIR.

While this is known to be approximately true in one case, it certainly was not true for the sandstone whose data are presented in Fig. 5. The ratio in question is plotted in Fig. 6, where curve *a* shows the ratio calculated from the data of Fig. 5 and curve *b* shows a similar set of ratios as obtained with another sandstone specimen.

The absolute accuracy of the measurements is not such as to guarantee that the ratio falls below the expected value in the neighborhood of the critical saturation, but there can be little question about the fact that there is a systematic variation with saturation in the apparent wettability of the rock. In order to see how this can be, one must classify the points of the interstice boundaries according to the saturation at which they are touched by the fluid interface. The lines of contact of the air-liquid meniscuses with the interstice walls occur, at high saturation, only in the largest spaces and at the places most distant from the points or lines of contact of the grains of the porous medium. At low saturations the high capillary pressure permits the meniscuses to touch only the finer, powdery grains and places very near the points of contact of the larger

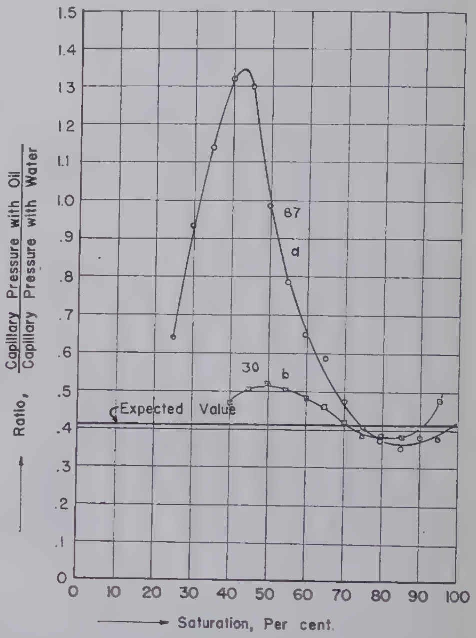

FIG. 6.—RATIO OF CAPILLARY PRESSURE MEASURED WITH KEROSENE AND AIR TO CAPILLARY PRESSURE MEASURED WITH WATER AND AIR.

The curves are believed to indicate that the interface contact with the rock interstices touches oil-wet surfaces at low saturations and water-wet surfaces at high saturations.

grains. In actual rock, the fines are very often clays and other kinds of soft mineral, while the larger grains are hard materials such as silica. It is also said to be true[13] that hard materials such as quartz, calcite and glass, as a consequence of their stronger molecular force fields, have a strong surface attraction for polarizable or polar liquids and hence are most often preferentially wetted by water. The silicates in particular may be arranged in a hardness series that corresponds with their wettability. It is not surprising, then, that the sandstone specimens cited show a repugnance for oil at high saturations but a strong preference for oil when the saturation is reduced to those values at which only the clays exert a significant capillary action upon the fluid boundaries.

In addition to the change of mineral nature with particle size, it may be expected, as a consequence of the selectivity of secondary mineralization with respect to curvature of the surface upon which secondary minerals are deposited, that there will be a variation of the nature of interstice surface with respect to distance from grain contacts, and hence a change of effective contact angle with saturation. For these and other reasons the curve of capillary-pressure ratio as shown in Fig. 6 may respond strongly to the mineral composition of the rock and to the manner of secondary mineralizations. If the kerogen and oily materials be classed as secondary minerals, the statement has even greater force.

Since the ratio of the capillary pressures at full saturation provides a measure of the relation between the contact angles, according to the work of Bartell and Osterhof,[8] it is an obvious generalization to assert that, similarly, the ratio of the capillary pressures at other saturations provides a measure of a contact angle that obtains at those saturations. This is only a partial truth, however, for the assumption made by Bartell and Osterhof[8,9] that the "effective capillary radius" is independent of contact angle is believed not to be strictly true. For the effective capillary radius is equal to twice the ratio of the volume of fluid moved against the entrance pressure to the area of solid surface thereby newly exposed* and it seems unlikely that this would be independent of the contact angle, especially in view of the variation with the wetting properties of the fluids of the quantity of fluid left behind after a flood. The error made is apparently not significant at full saturation, but at lower saturations the geometry of the lines of contact that mark the boundary between two fluids would vary considerably. There would not ever be an approximately fixed interface geometry that could be called independent of the contact angle. Hence the interpretation to be placed on the shape of the curve for the capillary-pressure ratio must be qualitative for the present. It measures roughly the wetting preference of the parts of the rock interstice surface that touch the fluid-phase boundaries within the rock, but the measurement is tainted by a variable geometry, which cannot yet be dealt with quantitatively.

USE OF THRESHOLD-PRESSURE PHENOMENA IN MEASUREMENT OF CRITICAL SATURATION OF SMALL SPECIMENS

In production by depletion, a very important property of rock is its critical saturation. It measures the quantity of oil a rock can hold without escape of gas; hence the proportion of oil that will be displaced from all parts of the depletion field before loss of gas occurs by flow through the sand. The distribution of liquid and gas within a rock is said to be critical provided a small decrease in liquid saturation would make continuously connected flow channels available to *both* liquid and gas, while a small increase in liquid saturation would leave the gas without continuously connected channels. The critical saturation is that saturation at which the critical distribution of liquid and gas obtains.[14] Because of capillary hysteresis, a critical distribution can occur at various saturations, depending on the previous history of the system. There is thus no single critical saturation for a given porous medium, but rather a range of critical saturations; there is, however, a definite largest critical saturation.

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* When a volume dV of fluid is moved against a pressure P, the work PdV is done. The energy thereby expended serves to remove fluid 1 from an area dA of solid, and replace it by fluid 2. If γ_1 and γ_2 are the adhesion tensions of the two fluids, respectively, on the solid, the energy stored in this process is $(\gamma_2 - \gamma_1)dA$. Since $\gamma_2 - \gamma_1 = \gamma \cos \theta$, where γ is the interfacial tension and θ the contact angle, we have $PdV = \gamma \cos \theta \, dA$, whence $2dV/dA = 2\gamma \cos \theta / P$, and the expression on the right is by definition Bartell and Osterhof's effective capillary radius.

In finding this critical proportion of gas by experiments upon small rock specimens, it will be found that as the saturation of the rock is slowly reduced, as by successive applications of blotting paper, the "threshold pressure" that is just sufficient to start the flow of gas through the wet rock becomes less and less, until finally, at the critical saturation, even an infinitesimal pressure difference will cause a steady* flow of gas proportional to the applied pressure. Thus one may locate the critical saturation as the saturation where threshold pressure becomes zero by successive measurements of the threshold pressure, beginning with the displacement pressure at full saturation and measuring threshold pressures at three or four saturations between that condition and the "critical saturation." The critical saturation will generally be observed below 85 per cent.

The explanation for the changes of threshold pressure can be found readily in terms of the geometry of the neck of rock where the droplet of water occurs that sets up this threshold pressure. In general, such necks will have tapering exits, as illustrated in Fig. 7. When the rock is fully saturated, as at 1, Fig. 7, an entering channel of gas will be constricted as always to the smallest diameter of the neck, but there will be no meniscus on the outlet side of neck to aid the pressure of the entering gas to overcome the obstacle. At a slightly lower saturation, however, there will be a meniscus on the outlet side as in 2 and 3 of Fig. 7, and it will be the algebraic sum of the pressures caused by the two curvatures that must be overcome by the threshold pressure. There are three distinct pressures attached to this situation; namely, the inlet pressure and outlet pressure of the gas and the pressure of the liquid. The threshold pressure is the difference between the pressure of the gas at the inlet and outlet faces of the rock. As defined, then, both the "threshold pressure" and the static "capillary pressure" are distinct *functions* of the saturation, while the "displacement pressure" refers only to full saturation and has only one value in any particular specimen.

In the sketches of Fig. 7, dotted lines are drawn to indicate the position and curvature of the meniscuses before the application of the gas driving pressure, and figures are attached to these dotted lines and to points on a corresponding curve of capillary pressure to indicate the progressive relation between the measurable threshold pressure *T* (small crosses), capillary pressures (dots on the full-line curve) and the hypothetical geometry of the droplet in a neck of rock as pictured. The small pipe leading in to the neck represents a connection between the droplet and the main body of liquid in the rock specimen. The neck in which the droplet occurs is effectively the smallest constriction of the most available continuous path from the entering (right side) to the outlet sides (beyond the sketch to the left) of the rock. The "pipe" will generally be a grain surface coated with a layer of clay, or a small-angled corner of the interstice.

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* In practice the steady condition is difficult to observe because even a slight pressure gradient causes a boundary effect. A good arrangement for checking steady flow is to drive the gas vertically upward through the specimen, using a pressure equal to the gravity head of liquid within the core.

In practice, the threshold pressure is not a perfectly reproducible function, probably because of the variability of the "pipe" connection. Only rough progression will be revealed, as in the crosses of Fig. 7. It is evident that if the pipe maintains pressure equilibrium, the outlet side (left) of the meniscus will not be displaced to a position of less curvature as shown by the full line. Instead, liquid will escape from the droplet through the pipe to the main body of interconnected capillary liquid as the nlet meniscus is driven into the neck, so that the curvature and position of the outlet meniscus is not changed. This will result in the measurement of a relatively low value of the threshold pressure.

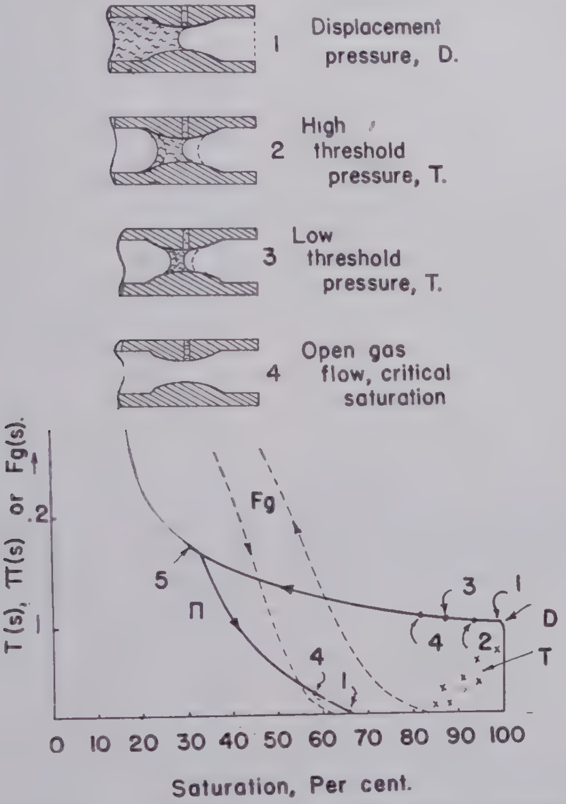


FIG. 7.—CHANGES IN THRESHOLD PRESSURE WITH SATURATION.

The drawings 1, 2, 3, 4 illustrate a possible origin for the variation of threshold-pressure measurements T (as shown by the crosses) with saturation. The situations 1, 2, 3, 4 can occur at a number of saturations, depending on the amount of trap hysteresis. F_g are relative permeabilities to gas. The arrows show the direction in which the saturation is being changed.

The value of the critical saturation is found to vary over a considerable range because of trap hysteresis. Thus, as shown by the imbibition curve of Fig. 2, the capillary pressure will fall toward zero if the core is permitted to suck up liquid from a point similar to the point 5 of Fig. 7, and when the capillary pressure is very low, plugging meniscuses may again form even at relatively low saturation. The conditions 1 and 4 of Fig. 7 may occur under imbibition conditions as low as 60 per cent, as shown by the data of Fig. 2. It is possible that a *lowest* critical saturation can be measured, but we have not yet been able to obtain sufficient reproducibility to be certain. The highest critical saturation is definite, however, and can be measured upon small rock samples (permeability plugs of one centimeter radius) by the technique indicated in this discussion. A vertically mounted Gooch-tubing core holder is convenient.[14] Great care is needed in testing the critical saturation of homogeneous cores having very flat capillary-pressure curves in order to avoid the piling up of liquid at the outlet end. Sometimes it is more convenient and just as accurate to test the first onset of zero threshold pressure—i.e., the critical saturation—by an instantaneous test, after allowing the core to "depolarize" or attain uniform saturation by seasoning with one face alternately up and down for short periods.

It will be important to decide which of the several critical saturations that can be measured in the laboratory will correspond to an actual field situation. There appears to be no other way than by careful field studies directed specifically toward the comparison to answer this question, and this has not been done. It is our belief that the critical (or equilibrium) saturation measured and defined by Wyckoff and Botset[15] corresponds to the greatest—i.e., the desaturation or desorption—value in the straight depletion case. However, it is readily possible that in some operating conditions—for example, in the case of imbibition of oil into a layer that has previously been stripped of its oil by expansion of a gas cap or during the geologic accumulation process—the *lower* critical saturations are effective. Much profit might result if practical operating procedures can be devised to secure in the field the advantages of the very low critical saturation that can be achieved with formation rock in the laboratory.

MISINTERPRETATIONS OF PHENOMENA OF DISPLACEMENT PRESSURE AND THRESHOLD PRESSURE

It is still sometimes believed,[16] in spite of all the laboratory experimental evidence brought forward against it,[7,14,15] that rocks containing gas and liquid are impermeable in the sense that large pressures, proportional to the length of the rock, are necessary to cause movement of the fluids. The present data on capillary hysteresis and this discussion of threshold pressures may tend to continue this error by showing that rocks can be impermeable (i.e., have critical saturations) at saturations even as low as 50 per cent. It should be observed carefully, however, that gas flows easily through rocks (probably in the form of separate bubbles) at saturations above the critical whenever the threshold pressure is exceeded, and that no threshold pressure greater than the displacement pressure can be observed in rock, however long the specimen or however great the assumed drainage radius. It has been erroneously believed possible to *sum* threshold pressures over each increment of length of rock because of a false resemblance between the known properties of necked circular cylinder glass capillaries, whose threshold pressures *are* additive, and the properties of rock, whose threshold pressures *are not* additive. This absence of high Jamin pressures has been proved for particular cases by several laboratory experiments in which the pressure distribution along flow tubes is measured during flow. Figs. 1 and 2 show why—namely, that liquid channels in any irregularity or departure from true roundness of a passage will permit the equalization of pressure by liquid flow past the bubbles. The threshold-pressure discontinuity, an essentially static phenomenon, occurs only in the gas (or nonwetting) phase; the wetting phase has not been shown to experience a static pressure discontinuity in a natural rock.

It is unlikely that a rock showing such discontinuity exists.

A clear view of the situation requires a sharp distinction between *viscous* pressure differences, which always occur as gradients proportional to the rate of flow of a particular fluid and which do rise to high values in an oil field, and the *capillary* pressure differences, which always occur as sharp discontinuities in pressure across phase boundaries; which are not associated with viscous flow, and which never exceed the pressure caused by the most highly curved phase boundary in the rock. The capillary pressure is *everywhere the same* in a rock in equilibrium, although trapped bubbles, which do not have any effect on pressure distribution other than to act as plugs to viscous flow of liquids, may individually have many curvatures (for a few days). Threshold pressure, being a pressure difference between two points in the same nonwetting phase, involves the difference in curvature between *two* phase boundaries (opposed meniscuses) and *only two* wherever, as with real materials, a droplet or bubble of one fluid cannot stop by complete plugging the tendency of a second fluid to relieve pressure differences caused by the plug.

DISCONTINUITY OF OUTLET BOUNDARY PRESSURE

Leverett[6] has discussed the equations governing the flow of a liquid and a gas through a porous medium when capillary pressure is taken into account and has shown the solution for the case of one-dimensional steady flow may be reduced to quadratures. When more than one porous medium is involved these equations of motion must be supplemented by boundary conditions that should obtain at the boundaries between the different media. It is easy to see what these boundary conditions must ordinarily be when steady flow conditions prevail: the rate of flow of each fluid must be the same on both sides of the boundary, and ordinarily the pressure in each fluid must be the same on each side of the boundary, since mobile interconnected masses of each fluid will be in direct communication with each other across the boundary. The capillary pressure must therefore be the same on both sides of the boundary, and hence the suturation must change discontinuously as the boundary is crossed if the two media have different capillary-pressure curves.

When they are applicable, these two boundary conditions (continuity of the rates of flow and of the capillary pressure) suffice to determine the proper solution. However, it is not always possible to apply both conditions in a straightforward way. One important case in which the two conditions are not directly compatible occurs at the outflow face of a porous medium from which both gas and liquid are emerging into free space. The free space may be regarded as a porous medium with 100 per cent porosity, infinite permeability, and zero capillary pressure. An attempt to apply directly the boundary conditions fails, for the continuity of the capillary pressure requires that the capillary pressure inside the porous medium be zero, and zero capillary pressure occurs, if at all, only at saturations above the critical at which a steady flow of gas cannot be maintained. A satisfactory formal solution to the equations of motion can be found for this case, however, and the chief characteristics of this solution can be discovered without actually making the calculation. The liquid saturation at the outflow face must not be less than the critical saturation; for if it were, the usual boundary conditions would apply, and we have just seen that they do not. But the saturation cannot be greater than the critical saturation at any finite distance from the boundary; for if it were, the steady flow of gas could not be maintained in this region of high saturation. The saturation therefore must rise as the gas nears the outflow face and must approach the critical value there. Since the liquid permeability at these saturations is finite, so also is the liquid-pressure gradient, and the liquid pressure is continuous across the face. The gas pressure gradient, however, must increase without limit as the outflow face is approached, in order to maintain gas flow with vanishing gas permeability. The gradient of the capillary pressure therefore must also become infinite at the boundary, and this infinite capillary-pressure gradient requires in turn an infinite saturation gradient to support it. The most interesting feature of this solution is the discontinuity in the gas pressure that occurs across the outflow face. Just inside the porous medium the saturation has the critical value and the gas pressure is larger than the liquid pressure by an amount equal to the capillary pressure at critical saturation. Outside the porous medium the capillary pressure is zero and the gas pressure is equal to the liquid pressure. Since the liquid pressure is continuous across the boundary, the gas pressure must fall discontinuously as it leaves the porous medium, by an amount equal to the *capillary pressure at critical saturation.*

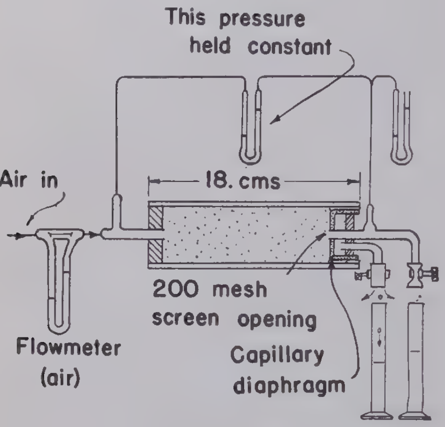


Fig. 8.—Apparatus for testing effect of an artificial capillary outlet boundary on gas-oil ratio.

Air is driven through a pack of 100 to 200-mesh Antioch sand, and the bottom of an Alundum extraction thimble serves as the artificial boundary.

Of course, the solution discussed above is only a formal solution to rather idealized equations of motion, and the conditions indicated by the solution transcend those under which the concepts employed are valid. To define saturation, for example, it is necessary to consider the average fluid content over a region which, while it may still be small on the macroscopic scale, nevertheless must be large compared with the diameter of a pore. A saturation gradient of the order of the reciprocal of a pore diameter is therefore physically meaningless. Nevertheless, there is a general correspondence between the idealized solution and reality. Near the outlet boundary, the gas, heretofore in an interconnected web, is forced into separate bubbles within the highly saturated boundary region. The infinite gas-pressure gradients given by the theory correspond to the physically extreme pressure gradients that occur in the explosive breaking of the bubbles.

The gas-pressure discontinuity at the outflow face appears to have been observed previously without its true nature being recognized. During some experiments on the flow of gas-liquid mixtures through consolidated sand, Botset[17] measured the gas pressure at various points along a long cylinder of Nichols Buff sandstone while a mixture of carbon dioxide and water was being produced from it by depletion. He found that after the liquid saturation was reduced sufficiently to permit gas to flow, the curve of gas pressure against distance from the outflow face, when extrapolated in a reasonable way to the outflow face itself, did not indicate that the gas pressure at the outflow face was zero, but rather about 0.08 atmospheres (see Botset's Fig. 8). This he ascribes to a clogging of the outlet valve and tubing by gas bubbles. It seems, however, much more reasonable to suppose that the valve was not appreciably stopped up and that the observed pressure drop was due instead to the natural discontinuity revealed by the theory mentioned above, for it remained, throughout the depletion, independent of the gas-water ratio and the rate of flow. To find the order of magnitude to be expected for the gas pressure discontinuity in this case, we note that the permeability of Nichols Buff sandstone was 500 millidarcys. Taking 80 per cent for critical saturation and using Eq. 1 to represent sandstones of this type, we find for the discontinuity a magnitude of $1.5/\sqrt{500} = 0.067$ atmospheres. The agreement with the observed effect is reasonable, in view of the departure of individual capillary-pressure curves from the average curve of Eq. 1.

It is evident that a high critical displacement pressure, which will be inversely proportional to the diameter of the largest effective hole in which bubbles are formed and broken at the outlet face, will be a substantial advantage in the production of the wetting phase. Since the outlet face of a well is amenable to treatment, it is not unreasonable to suppose that any process that will increase the displacement pressure there may sufficiently increase the efficiency of production from the field to repay the cost of the treatment.

For example, if the sand contains no mobile water and has an oil-wet outlet surface whose displacement pressure is as great as that of the 12-millidarcy core of Fig. 2, and if the main body of the sand has a capillary-pressure curve like that of the 148-millidarcy core of Fig. 2, one could in principle produce *all* of the main body of a horizontal thin reservoir without limit as to distance, down to a saturation of 52 per cent without *any* loss of free gas. By keeping back pressure on the well so that the pressure difference between the gas in the formation and the gas in the well is just less than the displacement pressure of the 12-millidarcy material, one could prevent free gas from bubbling through into the well. The oil, however, would not suffer any capillary-pressure discontinuity at the well surface, for it is the wetting phase. Hence the whole 148-millidarcy formation would empty itself into the well, the driving pressure at every stage being equal to the difference between the 148-millidarcy core's capillary pressure and the 12-millidarcy core's displacement pressure. Production would cease at 52 per cent, for there the capillary pressure of 148-millidarcy formation is equal to the displacement pressure of 12-millidarcy material. Finally, the process, in equilibrium, would have produced 48 per cent of oil, but with very little loss of formation pressure.

EXPERIMENTAL DEMONSTRATION OF EFFECT UPON PRODUCTION EFFICIENCY OF AN INCREASE IN THE OUTLET PRESSURE DISCONTINUITY

The illustrative example above, chosen to emphasize the importance of the distinction between the capillary resistance and the viscous resistance in the boundary effect, describes a case in which no gas pressure is available to move gas. If the pressure difference across the outlet surface is somewhat greater than the critical displacement pressure, gas will flow, but at a rate determined by the pressure that remains after subtracting the critical displacement pressure from the applied (or formation) pressure. Thus, as the total pressure is increased, one should pass smoothly from production at a zero ratio of free gas to oil through a range of very efficient gas-oil ratios until finally the purely viscous control of gas-oil ratio obtains at pressures that are several times the displacement pressure.

If these theoretical inferences are valid, one should be able to verify these predictions with a simple flow experiment designed to test the effect upon gas-oil ratio of an outlet face of tight porous substance. If the production through such a plate of high displacement pressure is definitely better than it is when production takes place through a simple boundary of the reservoir material, the theory is supported.

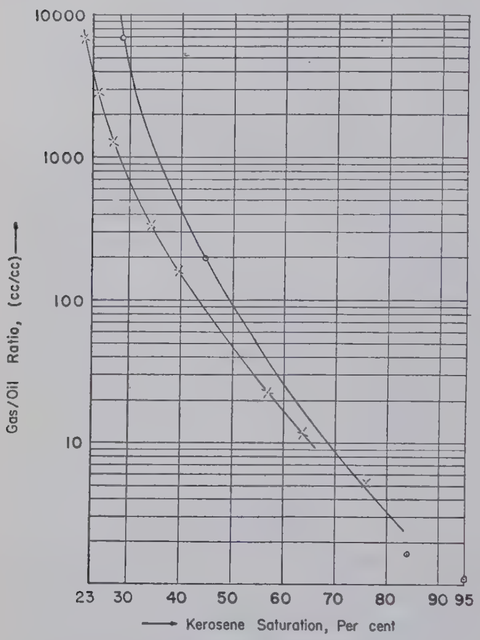


FIG. 9.—IMPROVEMENT IN GAS-OIL RATIO OBTAINED BY REPLACING OUTLET FACE WITH FINE-GRAINED POROUS DIAPHRAGM.

The circles (data without the diaphragm) and crosses (data with diaphragm) were obtained during one gas-drive operation by alternating the pinch clamps shown in Fig. 8, waiting long enough to establish current rates in each case.

The apparatus used in such a test is shown in Fig. 8. It consists of a pack of 100 to 200-mesh Antioch sand and kerosene arranged to produce by air drive either through an outlet capillary diaphragm or in the usual way through a hole in this diaphragm. By alternating the outlet surfaces, data were obtained for the gas-oil ratio at various saturations and for either outlet face. The change was made from one outlet to the other as soon as equilibrium was verified at each stage. The drop in pressure across the sand pack was held constant by increasing the total applied pressure when the diaphragm was interposed in order to overcome the additional displacement pressure and viscous resistance.

The pack was prepared by dropping Antioch sand into a glass tube of 2.5 cm. internal diameter containing kerosene. Into one end of the tube there was sealed (with de Khotinsky cement) an artificial capillary diaphragm consisting of the lower 11 mm. of a 25 by 70-mm. Norton alundum extraction thimble. Through a hole in the bottom of the thimble a ⅛-in. copper tube was inserted, which had a 200-mesh copper screen soldered over the end, and the tube was allowed to extend into the sand about one millimeter beyond the inner thimble surface. It was sealed in with de Khotinsky cement, and was further supported as shown with a brass washer to prevent strain. This tube was used to measure the pressure at the inside of the capillary diaphragm (the thimble) and also to collect the production of kerosene when not flowing through the diaphragm. A second copper tube carried the flow when it occurred through the diaphragm.

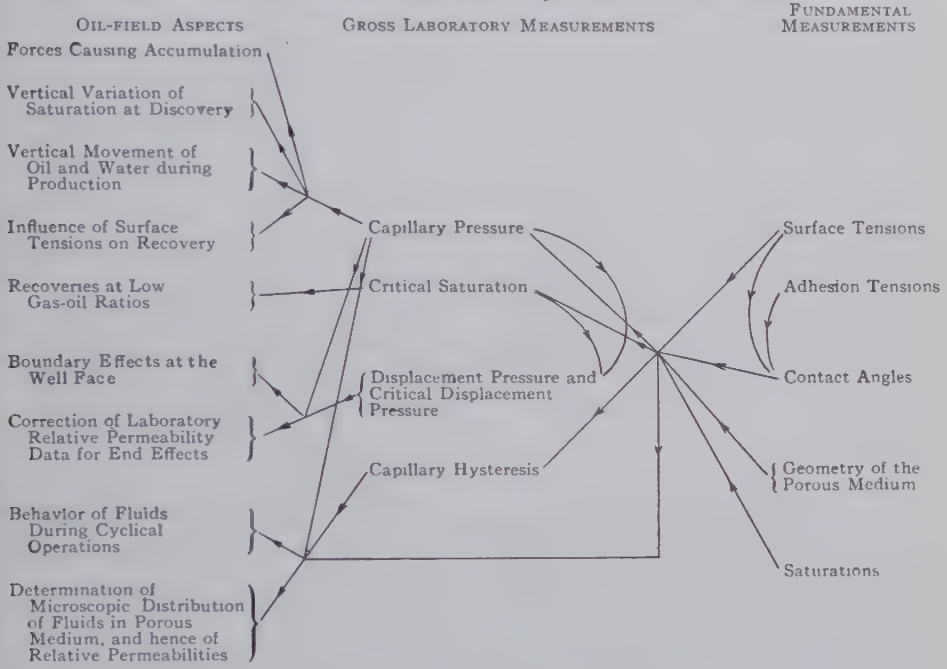
The displacement pressure of Antioch sand with kerosene is about 2 cm. of mercury, while the displacement pressure of the capillary diaphragm with kerosene is about 5 cm. of mercury. The pressure drop through the sand section of the pack was held at 4.1 cm. of mercury. Flow was nonturbulent in all stages.

The results are shown in the form of two associated curves of gas-oil ratio (Fig. 9), one obtained through the diaphragm (crosses) the other obtained without a diaphragm in the normal way. It may be concluded that a substantial improvement in gas-oil ratio was obtained by the use of the diaphragm, and that the theory is thereby supported. It took twice as much gas to produce 1 c.c. of kerosene in the normal way at 50 per cent saturation as it did through the extraction-thimble diaphragm and three times as much at 35 per cent.

APPLICATIONS TO OIL EXPLOITATION ENGINEERING

From the viewpoint of exploitation engineering, the subject of capillarity may be examined according to the classification of Table 1, a correlation chart of the various subjects. Part of the purpose of the chart is to point out the key position that might be occupied by the capillary-pressure function if suitable techniques for measurement were available, and to emphasize the academic or indirect position occupied by the quantities in the third column.

TABLE 1.—*More Important Causal Relations of the Problems and Measurements*


OIL-FIELD ASPECTS
GROSS LABORATORY MEASUREMENTS
FUNDAMENTAL MEASUREMENTS
Forces Causing Accumulation
Vertical Variation of Saturation at Discovery
Vertical Movement of Oil and Water during Production
Influence of Surface Tensions on Recovery
Recoveries at Low Gas-oil Ratios
Boundary Effects at the Well Face
Correction of Laboratory Relative Permeability Data for End Effects
Behavior of Fluids During Cyclical Operations
Determination of Microscopic Distribution of Fluids in Porous Medium, and hence of Relative Permeabilities
Capillary Pressure
Critical Saturation
Displacement Pressure and Critical Displacement Pressure
Capillary Hysteresis
Surface Tensions
Adhesion Tensions
Contact Angles
Geometry of the Porous Medium
Saturations

The first column (at the left) lists a number of problems of direct importance, which seem to depend, completely or in part, upon the measurements listed in the second column. The second column tabulates capillary measurements that have been made upon rock in a laboratory. The third column shows the classical molecular constants ordinarily used, to the exclusion of the measurements in column 2, in discussions of this kind.

A more complete chart would add the subjects of viscosity to the third column and of mixture permeability to the second, in a separate but parallel position. Only in purely static problems, such as that of the equilibrium distribution of fluids at discovery, can one use the ideas of capillarity alone, but here an attempt is made to avoid the aspect of viscous resistance in the interest of simplicity.

ACCUMULATION OF OIL

The question of what role capillary forces play in causing the accumulation of oil may be considered first. It is evident that any tendency of oil and water to exchange their presumably dispersed connate positions for the oil accumulation as found when a field is discovered can be expressed in terms of pressure difference that existed between the fluids in the two connate positions and a resistance to flow. In many of the previous writings on this problem, the thinking has taken the form of qualitative arguments directly from the *academic* quantities in the third column to the question of tendency to accumulate in the first. In the present approach, one would measure directly the pressure difference between oil and water (the *capillary pressure*) in a shale like the source shales, and between oil and water in the coarse sand of the reservoir, both in as nearly the original form as possible. The difference measures the tendency of the shales to suck water out of the coarse sandstones as a capillary driving pressure that can be stated in atmospheres. Thus whenever the mean oil saturation is greater than critical, so that a permeability to oil and to water can be measured, a complete theory can be applied to estimate the rate of oil accumulation and the distribution of saturations that will obtain when equilibrium is reached.

In this type of argument no use is made of the academic quantities in the third column, for if it is possible to place a rock specimen in the interesting condition, the correct capillary-pressure values are obtainable directly. In the present case it will be necessary, of course, to do some thinking in terms of the quantities of the third column in order to be sure that the conditions of measurement are correct. But to attempt to discuss oil accumulation directly in terms of surface tensions and contact angles is like trying to discuss the baking of biscuits in terms of the molecular constants of starch.

The phenomenon of accumulation is believed by the present authors to be dominated by the influence of capillary pressures, especially in the case of the currently interesting stratigraphic traps. Typical capillary-pressure differences have an oil-moving power equivalent to perhaps 100 ft. of closure. The contrary opinions seem to be bolstered principally by an experimental result obtained by Illing,[18,19] who showed that oil and water do not respond to the urging of what he thought should be the capillary forces by exchanging position in tapered glass tubes. He concluded that water and oil do not move in rock in primary response to capillarity. In our experiments with rock, which is considerably unlike glass capillaries, we have found that rock does suck up oil, even when saturated with a wide range of contents of water. The strength of this suction is shown in atmospheres for a particular specimen in Fig. 4. This is a *real* suction; the water-soaked specimen will draw up several per cent of oil (without excessive hysteresis) at nearly every point of the ternary diagram of Fig. 4 where the suction has been measured; or, conversely, will resist, with the pressure stated on Fig. 4, the removal of oil. It will do so whenever proper capillary contact is made, whether with oil in a tube or oil from another rock bearing oil under more or less capillary suction. While we do not yet have much information on three-phase interchanges under capillary forces in rock, it appears that Illing's experiment definitely does not have the meaning that has been attributed to it.

Equilibrium Vertical Distribution of Oil

It is a plausible hypothesis than an oil field that has lain undisturbed for a geologic time period is in capillary equilibrium. In such a case a free water surface will exist at the bottom of the pool, and above this position the capillary pressures will be determined by the gravitational potential, which in turn is controlled by the density differences of the fluids.

Let it be supposed that a core has been obtained from a discovery well in such a formation, and that the functional relations between the capillary pressure and the saturation, as in Figs. 1, 2, 3, and 4, have been determined for all core specimens obtained from the well at the various depths, and under the subsurface conditions. Then, if a valid saturation measurement can be obtained on any *one* core specimen (as by choosing one so impermeable as not to be affected by drilling water), it is possible to infer the saturation of *every other* specimen in terms of this one measurement and the densities of the fluids.

Let it be supposed in addition that all layers of rock do not vary laterally. Then if a structure map is available one can determine the saturation at every point in the field, and, in particular, can locate the position of edge water for every layer, and the position of the gas contact for every layer, in terms of one valid saturation measurement.

Actually, it appears that the suppositions are much too optimistic. In particular, it is known that in at least one field the saturation conditions do not conform to the capillary pressures; this, of course, had to be inferred from measurements made upon extracted samples, using artificial fluids, and from rough guesses as to formation surface tensions and densities. In other cases it appears that capillary equilibrium can be revealed by present techniques within particular zones, separated by shale breaks from other zones that are not in equilibrium with the same free water surface.

It is likely that these ideas will prove useful in Schlumberger interpretation, because a rough correspondence can be established between the capillary-pressure curve, as measured in the laboratory with water and air, and the resistivity curve obtained from the hole. The resistivity-saturation relation[20] provides the connecting link.

EFFECT OF CAPILLARITY ON MULTILAYER FLOW

It has been pointed out earlier in this paper that where variations in the capillary properties of rock along the direction of flow are such that the outlet face (i.e., the well) is in relatively tight rock there may be obtained an improvement in the gas-oil ratio that depends on the enhancement of the boundary discontinuity in gas pressure and may be of practical importance where flow rates are low. Similar important effects of capillarity will be obtained[14] when a well is producing from two or more layers that are in permeable contact with each other but have different permeabilities and capillary-pressure curves. While the forces involved in the motion of the fluids horizontally toward the well may be large compared with the capillary forces, the motions of the fluids vertically between the two layers is governed principally by capillarity. Since the area over which these forces act is very large, the total flow from one stratum to another may be considerable. The capillary action depends on the disturbance of capillary equilibrium by reason of the unequal depletion of the several connected strata of differing permeability. The capillary forces may either aid or oppose gravity, depending on the circumstances; and on the relations between these forces will depend the answer to such questions as whether the well should be produced continuously or with alternate periods of shutdown, where packers should be set for a contemplated gas drive, and so forth.

SUMMARY

Data are presented giving the relations between capillary pressure and saturation for representative sandstones and dolomites, for both two-phase and three-phase conditions. Improved definitions of capillary pressure, threshold pressure and displacement pressure are presented. The

concept of capillary hysteresis is widened to include "trap" as well as previously accepted "optional" hysteresis, and these new terms are defined.

The various occurrences of the displacement-pressure phenomenon as a maximum threshold pressure, as a minimum capillary pressure and in the Bartell cell are discussed. The theory of capillary flow at the outlet boundary is developed to reveal the occurrence there of a pressure discontinuity in the nonwetting phase equal in value to the capillary pressure at critical saturation.

An outline of the subject of capillarity from the point of view of exploitation engineering is presented, with brief mention of the special problems of oil accumulation, the equilibrium vertical distribution of oil, and multilayer flow.

ACKNOWLEDGMENTS

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Role of Connate Water in Secondary Recovery of Oil

By Parke A. Dickey* and Robert B. Bossler,† Members A.I.M.E.

(New York Meeting, February 1943)

Abstract

THE presence of connate water in oil sands is of far greater practical significance in secondary oil-recovery operations than it is in primary operations. The percentage saturations of oil, water, and gas in a depleted field determine whether it will be economically possible to recover oil by secondary methods, and whether water-flooding or gas-driving, or either, will be successful.

It is suggested that economic recovery of oil by secondary water-flooding can occur only when a rich bank of oil is formed by the encroaching water. If the sand has a greater effective permeability to water than it has to oil before flooding, a bank will not be formed, and water-flooding will not be successful, although gas-driving may be. Published results of laboratory work indicate that the effective permeability of a sand to oil and water depends primarily on the saturation of the sand by these phases. They also indicate that a small difference in relative saturation produces a large difference in effective permeability to the phase in question. There thus exists a critical range of saturations, wherein a small change in oil and water content of the sands will make water-flooding possible or impossible.

In gas-drive operations the water saturation is less critical but no less important. The presence of connate water in a sand increases the proportion of the residual oil that may be recovered by gas drive. Sands containing oil saturations too low and water saturations too high to make water-flooding possible can often be subjected to gas drive with economic recovery of oil.

The results of laboratory work on test samples that do not contain water cannot be applied to normal field operations. More tests on cores containing water as well as oil are desirable, and the improvement of coring technique is necessary. However, sufficient data are already available to enable an operator to use core data intelligently in estimating the chances of a secondary oil-recovery program.

Introduction

In recent years laboratory work has led to a much better understanding of the principles of oil-reservoir performance. The general principles of the expulsion of oil from sandstone by gas or water were developed by geologists of the Second Geological Survey of Pennsylvania in the 1870's[1] but only recently has the mechanism of gas or water drive been intensively investigated. Most published articles have applied the facts established in the laboratory to the primary production of oil from flush fields. This paper is not based on any new observations, but is an attempt to apply some of the conclusions obtained in the laboratory and described in the literature to the recovery of oil from depleted pools by secondary methods.

One of the most important factors that determine whether or not a secondary-recovery operation is economically successful is the ratio of injected fluid to oil recovered. This ratio may be expressed as the over-all or cumulative gas-oil ratio if gas is the driving medium, or water-oil ratio if water is the driving medium. Recent theoretical and experimental work has shown that the relative amounts of

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* Forest Oil Corporation, Bradford, Pa.

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[1] References are at the end of the paper.

gas, oil, or water that are flowing in a sand at a given point by reason of a pressure difference depend on the saturation of the three phases in the sand at that point. It has long been recognized that a sufficient oil saturation is a requisite to secondary-recovery operations. It has not, however, been sufficiently emphasized that the gas and water saturations are equally important in determining the over-all gas or water-oil ratios of the operation. A small variation in the gas or water saturation of a sand may determine whether water or gas can be used most efficiently as the driving medium.

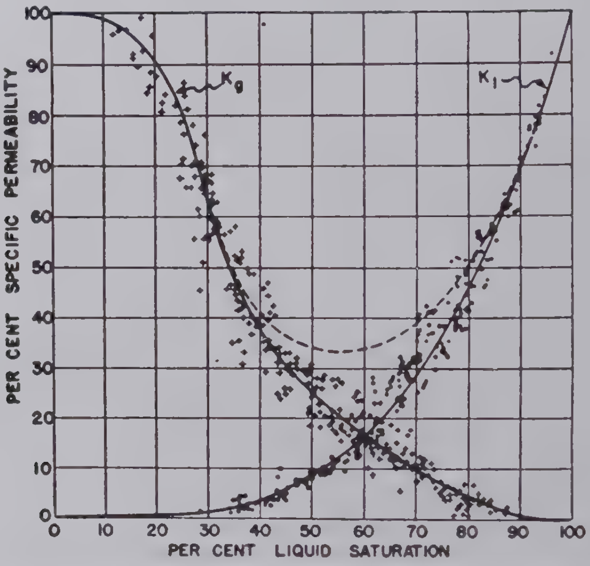

Fig. 1.—Composite curve showing variation of relative permeability with liquid saturation in unconsolidated sands.
From Wyckoff and Botset.[4]

Steady-state Flow of Fluids through Sand

It has been shown repeatedly that most producing oil sands contain appreciable quantities of connate water. The first laboratory determination of the oil content of a sample of oil sand known to the authors was by Charles R. Fettke[2] in 1926. He found as much as 40 per cent water present with the oil, and although he believed, probably correctly, that much of the water may have entered the sand during drilling, he was the first to point out that there was no reason to assume that an oil sand was originally 100 per cent saturated with oil. The significance of the presence of water in an oil sand was not generally appreciated until more than 10 years later.

Schilthuis[3] expresses the opinion that in most places the reservoir rock is completely wet with water and does not contact oil or gas directly. Under certain circumstances it appears possible that oil may be in contact with the solid phase. All normal producing sands, however, contain water, oil, and gas, and it is generally conceded that the water is present in the finer pore spaces, at the junction of grains, and probably wets a large proportion of the internal surface of the reservoir.

The presence of this water, and its position, has a very important effect on the expulsion of oil by either gas or water. It would be expected that the mechanism of the removal of oil from a sand of which the internal surface was entirely wet with oil might differ greatly from the removal of oil from a sand of which most of the internal surface was wet with water. It is seriously questioned whether the results of laboratory work on samples 100 per cent saturated with oil can be applied to a field where the sand contains appreciable amounts of connate water. For example, in the rapid removal of oil from an oil-wet sand by water drive in the laboratory, the water would remain in the larger pores while oil would remain in the smaller ones and on the grain surfaces. This condition would be exactly the reverse of that believed to exist in most producing sands. Conclusions on the behavior of such a test sample would not apply to field conditions.

Wyckoff and Botset[4] showed, in 1936, that when a gas and a liquid were flowing simultaneously through a sand, the permeability to gas decreased as the liquid saturation increased. Similarly, the permeability to the liquid increased as the liquid saturation increased. Similar experiments by others[5,6,7] have checked the validity of this work.

A curve showing the change in effective permeability with liquid saturation, as determined experimentally by Wyckoff and Botset, is shown in Fig. 1. These authors also showed that in steady-state flow the gas-liquid ratio is determined by the ratio of the viscosities of the two phases, and the ratio of the effective permeabilities of the sand to them. This may be expressed:

$$\frac{V_g}{V_l} = \frac{k_g \mu_l}{k_l \mu_g}$$

Where

V_g = c.c. per sec. gas at mean pressure.
V_l = c.c. per sec. liquid.
k_g = effective permeability to gas.
k_l = effective permeability to liquid.
μ_g = viscosity of gas.
μ_l = viscosity of liquid.

Therefore, from the curves of Fig. 1, which give the effective permeabilities of the sand to the gas and liquid, and a knowledge of the viscosities of the fluids, the steady-state gas-liquid ratio may be computed easily.

To date only one study of the flow of all three phases—gas, oil, and water—has appeared.[8] This study by Leverett and Lewis, although exploratory in nature, provides some data showing how the fraction of each phase in the flowing stream changes with the saturation of that phase in the sand.

MECHANISM OF FLUID DISPLACEMENT

Buckley and Leverett[9] have investigated mathematically the displacement of oil by water and gas on the basis of the permeability saturation relationships outlined in the foregoing paragraphs. They show that the fraction of the displacing fluid moving at any given point in the sand depends on the viscosity of the fluid and its relative saturation at that point.

Take, for example, a point in an oil-rich sand that is being invaded by a water flood. Imagine that at this point the effect of the drive is beginning to be felt, but that the water has not yet reached the point. The oil saturation is high and the water saturation is low, so that more oil than water is moving under the effect of the drive. The moving oil displaces the gas, occupying the spaces that the gas occupied. The effect of the flow of fluids ahead of the drive will thus be to increase the oil saturation greatly, increase the water saturation slightly, and reduce the gas saturation to nearly zero. A rich zone thus accumulates ahead of the water front, which generally is called a "bank" of oil.

As the water reaches the given point, it displaces much of the oil and occupies the spaces formerly occupied by oil. This increases the water saturation of the sand, and therefore increases its permeability to water and decreases its permeability to oil. The proportion of oil in the flowing stream at the point thus decreases very rapidly, and continues to decrease as the water saturation of the sand increases. As the water continues to flow through the sand it will remove only very small additional quantities of oil.

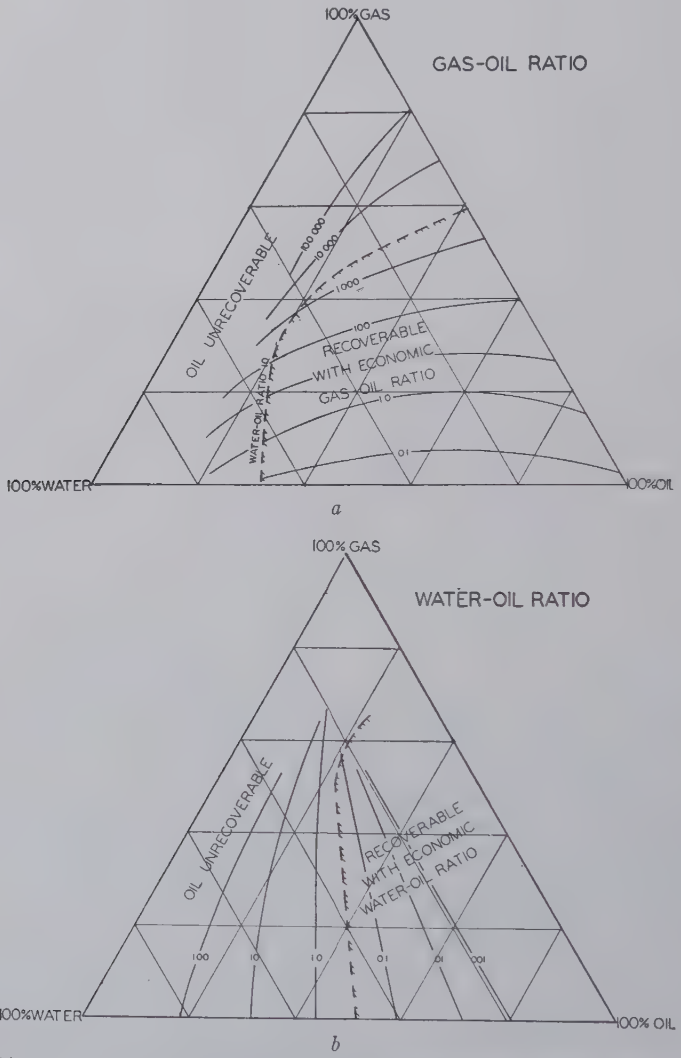

FIG. 2.—VARIATION OF GAS-OIL AND WATER-OIL RATIOS WITH SATURATION OF GAS, OIL, AND WATER IN UNCONSOLIDATED SAND.
From data of Leverett and Lewis.[8]

The first stage, when the flowing stream is principally oil, was called by Buckley and Leverett the "initial" stage, and the later stage, when the stream is mostly water, was called the "subordinate" stage. During the initial stage the oil is expelled by a shoving or piston action, and during the subordinate stage it is expelled by a frictional or shearing action. In the subordinate stage, the drive is relatively ineffective, as only small amounts of oil will flow for large amounts of water.

It seems probable that in actual secondary water-flooding operations virtually all the recoverable oil is removed during the initial stage. After the advancing water front reaches the producing well, the water-oil ratio is so high that only small and totally uneconomic quantities of oil are produced. A well will continue to produce oil for a long time after the water has broken through, but this is because certain strata of low permeability are still producing oil although others may be producing mostly water. In a normal flooding operation in the Bradford field, the water production does not begin to increase until oil production has about reached its peak; thereafter, total liquid produced usually increases, the oil decreasing and the water increasing because of the now higher permeability of the sand to water. This indicates that when the effect of the flood has fully reached the producing well nearly all the individual strata, even of differing permeability, are producing oil only. The water front then reaches the well successively in the various strata in inverse order of their permeability. Probably never does any single stratum produce commercial oil and water simultaneously.

These considerations suggest that in performing water-flooding tests on core samples ("flood pots"), only the oil recovered by small throughputs of water should be considered recoverable. Continued passage of water through the core under high pressure differentials will lead to the recovery of additional quantities of oil in the laboratory, which would be impossible to recover economically in the field.

A similar sort of action takes place when gas is the invading fluid. Initially, if the sand is well saturated with oil, a bank of liquid is pushed ahead of the gas, because the sand is more permeable to oil than it is to gas. As the oil is displaced by the gas, the permeability to gas increases very rapidly, and when the sand contains as much as 20 per cent gas, the gas flow by volume is approximately 20 times that of the oil.[6] This fact has given rise to the opinion, frequently expressed, that gas drives are fundamentally less efficient than water drives.

It should be remembered, however, that in most places it is uneconomical to attempt to recover oil by water drive after the initial or "bank" stage of displacement has passed, because large volumes of water must be handled to obtain relatively small quantities of oil. With gas as the displacing fluid, the initial stage is short-lived, and effects the recovery of only a small part of the oil even in the early life of a field, and it is never attained under secondary recovery methods in partly depleted pools. However, the low cost and ease of handling makes it possible to drive from 1000 to 5000 volumes of gas through the sand for each volume of oil recovered, hence, under certain conditions, especially those of low oil and high water saturations, gas drives may be much more efficient economically than water drives in the recovery of oil.

EVALUATION OF WATER-OIL AND GAS-OIL RATIOS FROM EXPERIMENTAL DATA

Leverett and Lewis[8] investigated the flow of gas-oil-water mixtures through unconsolidated sands. Their observational data are tabulated in their paper, and the composition of the flowing stream at various saturations is given. From these data the gas-oil ratios and water-oil ratios of the flowing stream have been calculated. The approximate values of the gas-oil ratio are shown by the curved lines in Fig. 2*a* and the water-oil ratio in Fig. 2*b*. These are triangular diagrams, the purpose of which is to represent saturation conditions existing in the sands being investigated. In these diagrams a sand saturated 100 per cent with gas would be plotted at the apex, while a sand saturated 100 per cent with water would fall in the lower left corner, and 100 per cent oil in the lower right corner. A sand saturated 33⅓ per cent with each component would fall exactly in the center of the triangle. Every possible saturation will thus appear as a point in the diagram.

The gas-oil ratios and water-oil ratios calculated from the data cited heretofore were inserted in the triangular diagrams alongside the point representing the condition of saturation existing when these ratios were observed in the flowing stream. The gas-oil ratios and water-oil ratios were then contoured by connecting points of equal value. Considerable irregularity in the values was noted, due in part to the use of oils of differing viscosity, and the contour lines are generalized and approximate.

Both diagrams show that no oil flowed when the oil saturation was below about 15 per cent. This illustrates the well-known fact that the oil saturation cannot be reduced below a certain point by any mechanical means. In Fig. 2*a*, as the gas saturation increases (i.e., going upward) the gas-oil ratio increases geometrically. This is in line with other published data showing the change in gas-oil ratio with saturation (Krutter's[7] Figs. 3 and 4). With increasing water saturation for any given oil saturation (following a line downward and to the left) the gas-oil ratio decreases. With a sand having saturation of 70 per cent gas and 30 per cent oil (no water) the gas-oil ratio is about 10,000, while with a saturation of 30 per cent oil, 20 per cent gas, and 50 per cent water the gas-oil ratio is about 5. At the former saturation gas-drive operation would be uneconomical, but at the latter would be successful, although the oil saturation in each case is the same.

The presence of water not only makes it economically possible to recover the oil, but it makes possible the ultimate recovery of a larger proportion of the oil originally in the reservoir. Krutter (Fig. 15 of ref. 7) shows that by gas drive the greatest recovery of oil, expressed in terms of percentage of oil originally in the sand, occurs when the water content of the sand is about 30 per cent.

The approximate range of saturations that may be economically driven with gas can be arrived at as follows. If the limiting economic gas-oil ratio is about 3000 vol. of gas per volume of oil (17,000 cu. ft. per bbl.), then, according to the data shown in Fig. 2*a*, sands containing more than 40 per cent oil with no water, or more than 20 per cent oil with 40 per cent water, can be driven with gas. At high water saturations the water-oil ratio becomes large. Since a water-oil ratio of about 10 vol. of water per volume of oil may be considered an economic limit, water saturations of the order of 70 per cent form a limit in this direction. Combining the 3000 gas-oil ratio line with the 10 water-oil line gives the limiting range of saturations for gas-drive operations as estimated from these data.

The water-oil ratio in a water flood (Fig. 2*b*) is controlled similarly by the relative amounts of water and oil in the sand. For an oil saturation of 45 per cent and a water saturation of 55, the water-oil ratio is 1; that is, the flowing stream will consist of equal parts of oil and water. If the oil and water saturations are such that more water than oil will flow, it appears that the concentration of oil to form a bank ahead of the flood cannot occur. The "initial" stage of displacement will be absent.

CRITICAL OIL AND WATER SATURATIONS

The foregoing reasoning, based on the published experimental data referred to above, indicates that some depleted oil sands may be economically flooded by water drive, and that other sands may not be flooded by water drive but may be worked effectively by gas drive, depending on the oil and water saturations of the sands. Furthermore, a very small difference in the relative saturation of oil and water in a critical range may determine whether the initial stage of water-flooding will occur, and therefore whether water may be used economically as a flooding medium.

For example, if a sand is more permeable to water than to oil before flooding, the initial or bank stage cannot occur, and the subordinate stage, although it may recover appreciable quantities of oil, will be uneconomical. The existence of a critical oil and water saturation may be inferred from the data of Leverett and Lewis, and it appears to be in the neighborhood of equal quantities of oil and water. Its exact value cannot be determined from their work, and probably it is different in different sands; also, undoubtedly it will vary somewhat with several other factors.

The viscosity of the oil enters directly into the equation determining the fraction of oil in the flowing stream and is important therefore in determining the critical saturations. It appears to be of much less importance than the oil-and-water saturations, which govern the effective permeability geometrically. Thus doubling the viscosity of the oil should double the water-oil ratio, while a decrease in oil saturation of only about 5 per cent would also double the water-oil ratio.

Doubtless the effect of capillary pressure[10] is also important. These pressures depend on the relationships of the interfacial tensions of the three fluids and the solid phase and are affected by the original distribution of the phase wetting the solids. The capillary forces unquestionably are important in determining the most advantageous rate of advance of the water. If the removal of oil is due to a combination of the effects of hydraulic and capillary forces, the optimum rate is that at which the resultant of the forces brings about the greatest recovery of oil. The question of whether oil or water predominantly wets the sand at the start of the flood cannot be neglected, certainly. For any given saturation of oil and water, it appears likely that the effective permeability to oil may be different if the sand is oil wet or water wet. It is even possible that at low pressure differentials the permeability of the wetting phase is increased while at high pressure differentials the permeability of the nonwetting phase is increased.

If the water saturation is so low that the oil of necessity wets a very large proportion of the solid surfaces, the residual oil left after the water flood may be comparatively high. Hence, too low a water saturation, especially if accompanied by a high gas saturation, may make water-flooding impracticable, as well as too high a water saturation.

The porosity, dry permeability, and pore-size distribution undoubtedly affect the relative permeabilities of a sand to oil or water. Their effect is closely associated with the capillary phenomena mentioned above. The results of tests on an unconsolidated sand cannot be applied quantitatively to a highly consolidated sand like those of Pennsylvania.

There seems to be no reason why all these conditions, which determine the critical relative permeability of a sand to oil and water, cannot be investigated in the laboratory, and routine tests developed to determine the possibility of recovering oil by water-flooding. It seems probable that the effects of viscosity and capillary phenomena are of a much smaller order of magnitude than the effects of actual percentage of pore space occupied by oil and water, at least in a normal water-wet sand.

In secondary oil recovery by gas drive, the formation of the initial or bank stage is less important than with water drive. Consequently, it may be that there is no critical range of saturation wherein a small variation will make the difference between success and failure. If gas is injected into a sand that has a gas saturation so high that mostly gas will flow, the gas-oil ratios will be high and the operation will be uneconomical. The gas-liquid ratio flowing depends on the relative amounts of gas and liquid in the sand, and it makes little difference whether the liquid in the sand be water or oil, at least for total liquid saturations greater than 40 per cent. Thus, if the liquid consists of equal quantities of water and oil, approximately equal quantities of water and oil will be moved through the sand. If the sand contained the same amount of oil, but no water, it would contain only one half as much liquid, and the gas-liquid ratio would be greatly increased. Thus, for a given amount of oil in a sand, the amount of oil recovered by gas drive will be affected by the amount of water in the sand.

Application to Field Operations

Even if the exact values of the critical saturations described could be determined in the laboratory for any sand, the problem of obtaining representative core samples from a prospective field of operations would remain. Much progress in the taking of cores has been made recently by the use of oil-base muds and pressure core barrels. It has become possible to estimate the connate water of a sand with a very fair degree of accuracy by means of electric logs. Fortunately, the low pressures in most fields undergoing secondary recovery facilitate the recovery of representative cores. In testing a field for secondary-recovery operations, it might be well worth while to take a core in the sand using regular mud and then immediately sidetrack the hole and take another using oil-base mud. One core would then give reliable oil saturations and the other reliable water saturations. In the Bradford field reliable cores are obtained regularly, probably because of the low horizontal and vertical permeability of the sand, which prevents flushing of the sand ahead of the bit. In looser sands, the problem is a good deal more difficult.

Although this discussion admittedly is speculative, and is based largely on laboratory work on unconsolidated sands, which cannot be applied quantitatively to field operations, there is some evidence that critical water saturations exist and are important.

In the Bradford field of Pennsylvania the average oil saturation is 40 per cent, and the average water saturation 30 per cent. Gas drives in this field have caused a much smaller and slower recovery of oil than have water drives. The inefficiency of gas drives was due in part to the low permeability, which averages 10 millidarcys. Water drives have been notably successful in this pool. In certain sections of the pool, however, the water saturation is higher than the average. It has been found that if the water saturation exceeds about 40 per cent, no "bank" is formed, and oil is produced at uneconomically high water-oil ratios. In one district, where the water saturation was about 60 and the oil saturation about 30 per cent, the initial water-oil ratio on flooding was about twenty to one.

In the Venango fields of Pennsylvania the normal oil saturation ranges between 25 and 35 per cent, and the water saturation between 40 and 60 per cent. In spite of very numerous attempts, no water-flood operation has been successful in these sands. In almost every case the water came through bringing very small and uneconomical quantities of oil. Gas driving, on the other hand, has been quite successful. Recoveries as high as 100 bbl. per acre-foot have been obtained, and 50 bbl. per acre-foot is obtained frequently. This amounts to a reduction in saturation of 5 to 8 per cent of the pore volume, which is rather remarkable considering the low initial oil saturations.

Districts in the Mid-Continent where water-flooding failed because of high water saturations in the sand are known, and are mentioned by Horner.[11]

At other places, water-flooding has been attempted on the basis of an oil content, expressed in barrels per acre-foot, much higher than normal for the Bradford field.

When expressed as saturation in percentage of pore volume, however, the oil saturations were lower than at Bradford, because of the high porosity of the sand, and the floods were failures.

ACKNOWLEDGMENTS

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Fingering and Coning of Water and Gas in Homogeneous Oil Sand

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(Los Angeles Meeting, October 1943)

Abstract

This paper is a theoretical analysis of fingering of water and coning of water and gas in homogeneous sand. Investigation of this idealized case illustrates the relative magnitude of the factors involved in actual conditions. The body of the report presents equations, example calculations, and charts that facilitate solution of such problems. Derivation of the equations introduced in this paper and a discussion of previously published equations are included in the appendix.

Introduction

Production of water from oil wells as a result of the pressure gradients established by flow of fluids through oil-producing sands is a common occurrence, which influences the cost of oil production, the degree of depletion and the efficiency of expulsion of oil from naturally occurring reservoirs. Control of water production and encroachment are important both in primary and secondary phases of oil-field exploitation in order to produce oil and gas at lowest cost and in order to achieve the greatest ultimate recovery of the oil in the reservoir. Although many actual oil reservoirs present a multitude of variables that influence fingering and coning of water and gas, an inspection of the relationship and magnitude of the forces involved in the case of a homogeneous sand may indicate satisfactory methods of controlling water production. Application of equations relating the variables may indicate the geometric type of drainage that exists in a particular reservoir or in the vicinity of a particular well.

A homogeneous sand body is assumed within the portion of the reservoir influenced by the well. Two geometric types of drainage are considered theoretically. The first is water fingering into an oil sand that is relatively thin compared with the lateral extent of the sand. This sand may represent the entire oil-producing reservoir or it may represent one interval in an oil reservoir, which is separated from other producing intervals by competent lithologic barriers to flow of fluids. For the condition of complete penetration of a well in such a sand body, it may be assumed that no flow occurs across bedding planes. A mathematical relation is developed between the limit of approach of a water finger to the well without being drawn into the well and the corresponding operating pressure drawdown.

The second condition considered is that of water or gas entry into an oil well as the result of coning through bedding planes. The theory and graphical solution developed by Muskat[1] for the limit of approach of a water or gas cone to a well, without its entry into the well, related to the corresponding maximum pressure drawdown, is reviewed and amplified. Charts are presented, which facilitate graphical solution of the problem. A method is presented for the extension of this type of graphical solution to the case where gas and water coning occurs simultaneously.

Water Fingering

Consider the case illustrated by Fig. 1. A water cusp is formed in a sand because of

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[1] References are on page 197.

the pressure gradients in the flowing fluid. Assume that a two-dimensional radial flow exists. The equation for the rate of flow involves the quantity ϕ, which is the velocity potential, a measure of the relative force at a point. The gradient of velocity potential is a measure of the force gradient causing flow, and for horizontal flow the pressure P may be used for the value of ϕ. However, for nonhorizontal flow the velocity potential is used to express the force causing flow, because it applies a necessary correction to the pressure at various points in the system. This correction amounts to

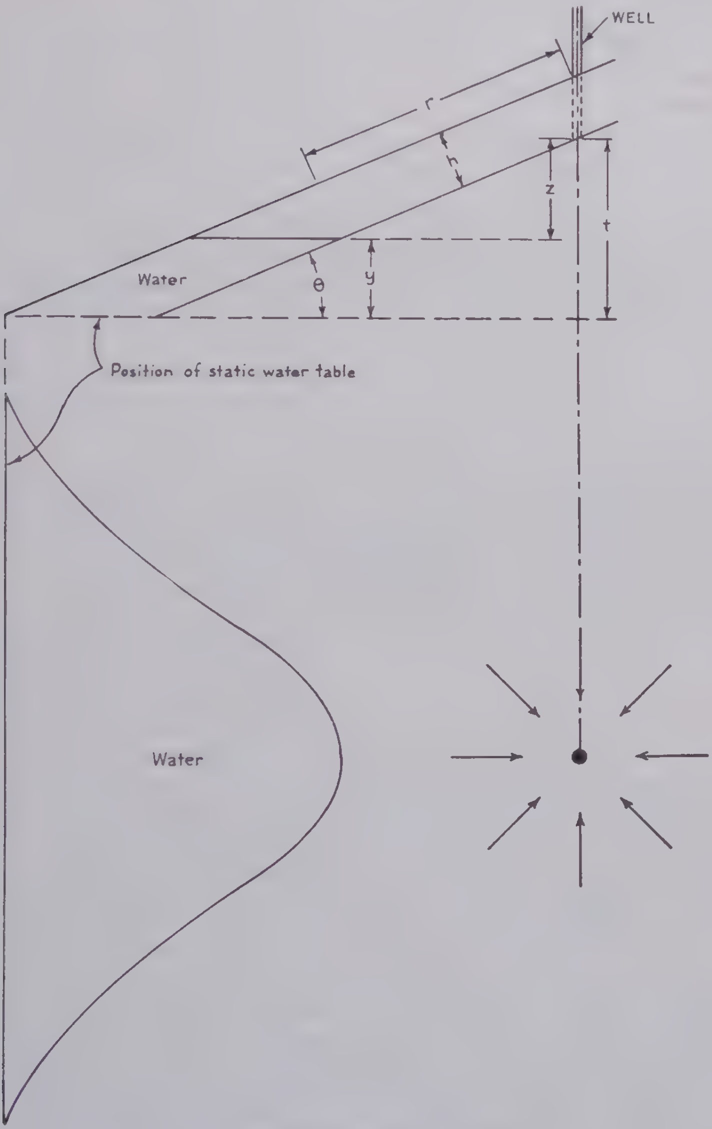

FIG. 1.—WATER-FINGERING CONDITIONS.

the portion of the difference in pressure between points that is due to hydrostatic gradient, the effect of gravity on the mass of fluid between points of different elevation. The rate of flow may be expressed by the following equation:*

$$Q = \frac{2\pi krh}{\mu}\frac{d\phi}{dr} \qquad [1]$$

where

$$\phi = P - \gamma_0 gz$$

In order for a water finger extending updip toward a producing well to be stable it is necessary that the pressure gradient at the top of the water surface equal the differential gravitational force between the water and the oil. This stable relationship is expressed by

$$\Delta\phi = \Delta P - \Delta\gamma g\left(t - \frac{dz}{dr}r\right) \qquad [4]$$

Combination of these two equations in the manner developed in the appendix gives Eqs. 12 and 15. The minimum distance that a finger can approach without being drawn into the well by an unstable condition is given by

$$r_{\min} = \frac{\Delta P}{\Delta\gamma g \sin\theta \ln\dfrac{r_e}{r_w}} \qquad [12]$$

The minimum vertical distance a well can be located above the static water table without fingering is

$$t_{\min} = \frac{\Delta P}{\Delta\gamma g}\left(\frac{1 + \ln\dfrac{r_e}{r_{\min}}}{\ln\dfrac{r_e}{r_w}}\right) \qquad [15]$$

The term r_e in the foregoing equations represents the drainage radius, which is the distance from the center of the well at which the static or shut-in pressure of the well exists during flowing conditions, and the difference between this static pressure and the flowing pressure at the well constitutes the drawdown pressure ΔP. For a value of static pressure measured after sufficient shut-in time has occurred to allow equilibrium to be attained, the corresponding value of r_e is the maximum radial distance from the well that influence extends in affecting pressure and drainage of fluid. Although usually this must be arbitrarily assumed it should be noted that throughout the practical range of the values in the relationship, large differences in r_e cause relatively small differences in the results, because the logarithm of the ratio of radii is employed. Where values of the other factors are known, the equations developed may afford a means of measuring an effective value of the drainage radius in a uniform sand.

To illustrate applications of Eqs. 12 and 15, consider the example defined by the following data:

Differential weight between water and oil $= \Delta\gamma g = 0.14$ lb. per sq. in. per ft. of depth.

Dip of sand $= \dfrac{dz}{dr} = \sin\theta = 0.1$

Well radius $= r_w = \frac{1}{3}$ ft.

For selected values of drainage radius of 600 and 6000 ft. and for the given conditions, the relationship between distance of the well above the static water table t and the drawdown pressure ΔP is presented in Fig. 2.

The asymptotic nature of the curves results from the fact that water cannot be drawn toward the well from a location beyond the drainage radius of the well.

WATER AND GAS CONING

Consider the coning of gas or water into a well that partially penetrates a homogeneous oil sand, as illustrated in Fig. 3. Theoretical development of this problem has been presented by Muskat,[1] who has shown that the following equation represents the relationship of the factors involved in a homogeneous sand:

$$\frac{\Delta\phi}{\Delta\phi_e} = \frac{\phi_w - \phi_z}{\phi_w - \phi_e} = 1 - \frac{g\Delta\gamma}{\Delta P}h\left(1 - \frac{z}{h}\right) \qquad [16]$$

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* Nomenclature at end of text.

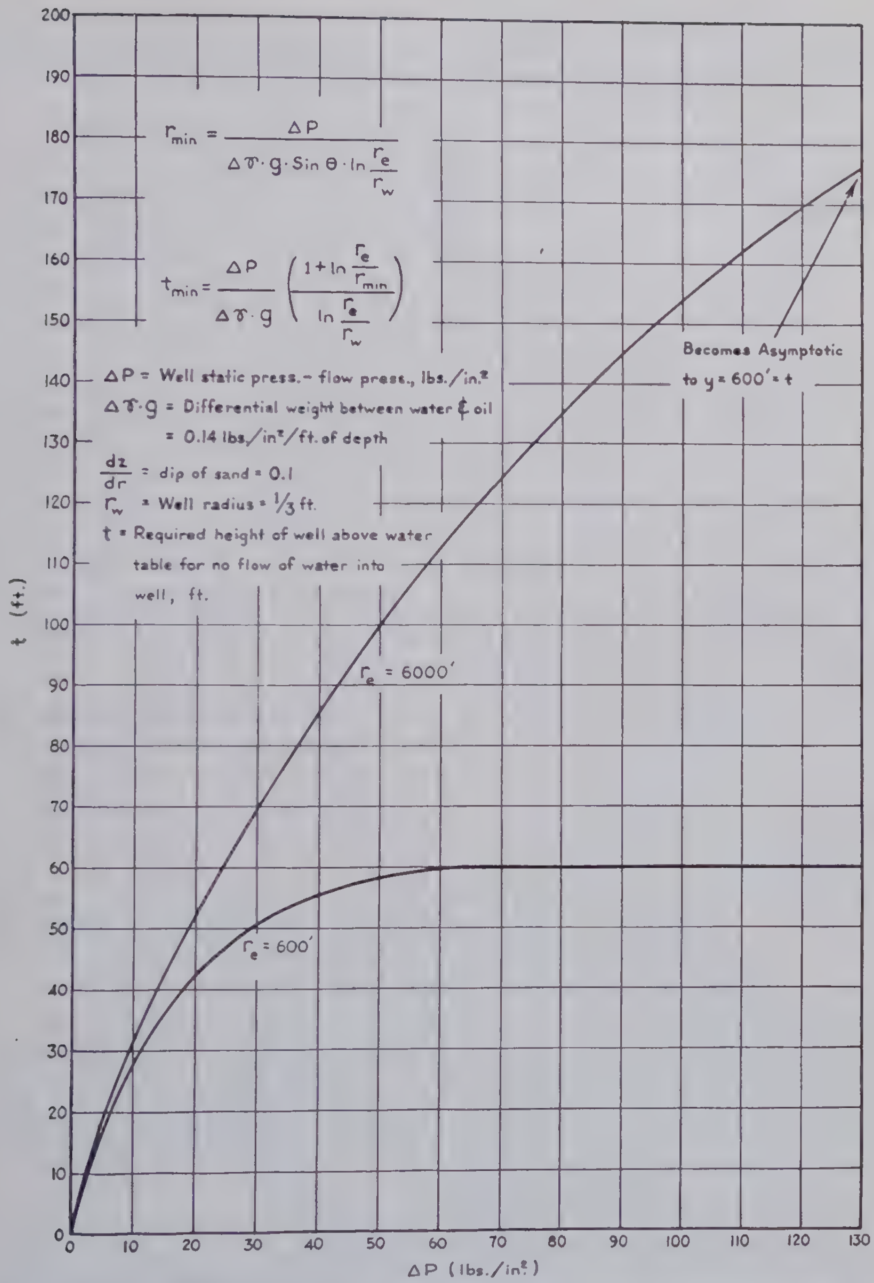

FIG. 2.—MINIMUM VERTICAL DISTANCE OF AN EXAMPLE WELL ABOVE THE STABLE WATER TABLE FOR WATER FINGER NOT TO ENTER WELL.

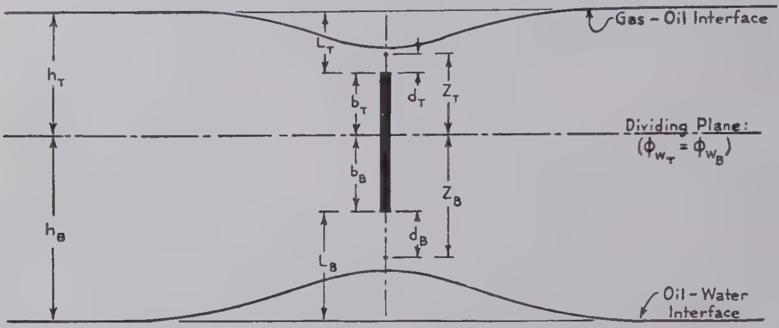

FIG. 3.—WATER-CONING AND GAS-CONING CONDITIONS.

Eq. 16 relates the potential forces set up in the fluid flowing in the sand to the differential gravitational forces between the two fluids involved. An explanation of equations expressing the velocity potentials is presented in the appendix. Fig. 4 presents a cross plot of values given by Muskat[1] for potential below the bottom of the well ϕ_z and potential at the well surface ϕ'_w for a particular value of well radius defined by the well-radius parameter ρ_w. Correction factors to be applied to ϕ'_w for values of well radius other than that on which Fig. 4 is based are presented in Fig. 5.

It is shown in the appendix that the velocity potential at the drainage radius may be expressed by:

$$\phi_e = 4qx \ln \frac{2}{\rho} \qquad [20]$$

GRAPHICAL SOLUTION OF CONING

For the case of water or gas coning to a well in which the penetration of the well extends from one boundary of the oil sand to a point some distance from the static position of the water or the gas, the solution may be obtained by the following procedure:

1. Determine the values of the potential ratio $\frac{\Delta\phi}{\Delta\phi_e}$ for various values of z from the charts presented herein and plot $\frac{\Delta\phi}{\Delta\phi_e}$ vs. $\frac{z}{h}$.

(*a*) ϕ'_w is given by Fig. 4 for the particular penetration of the problem and for a well-radius parameter ρ_w of 0.001.

(*b*) Correct the value of ϕ'_w to the value of ϕ_w corresponding to the radius parameter of the well by use of Fig. 5.

(*c*) For selected values of $\frac{z}{h}$, determine the values of ϕ_z from Fig. 4. ϕ_z is given as a function of well penetration, $\frac{b}{h}$, and the relative distance beyond the extremity of the well $\frac{d}{L}$.

(*d*) Determine ϕ_e for a reasonable value of drainage radius from Fig. 6.

2. Draw a tangent to the potential curve of $\frac{\Delta\phi}{\Delta\phi_e}$ vs. $\frac{z}{h}$ from the point $\left(\frac{\Delta\phi}{\Delta\phi_e} = 1, \frac{z}{h} = 1\right)$.

(*a*) The value of $\frac{z}{h}$ at the point of tangency represents the maximum height y of a stable cone. $\left(\frac{y}{h} = 1 - \frac{z}{h}\right)$

(*b*) Intersection of the tangent to the curve with the value $\frac{z}{h} = 0$ gives the value expressed by the following form of Eq. 16:

$$\left(\frac{\Delta\phi}{\Delta\phi_e}\right)_{\frac{z}{h}=0} = 1 - \frac{g\Delta\gamma h}{\Delta P}$$

3. From the graphically determined value of $\left(\frac{\Delta\phi}{\Delta\phi_e}\right)_{\frac{z}{h}=0}$ solve for ΔP, the maximum pressure differential without coning.

$$\Delta P = \frac{g\Delta\gamma h}{1 - \left(\frac{\Delta\phi}{\Delta\phi_e}\right)_{\frac{z}{h}=0}} \qquad [21]$$

An additional step is required in the solution of the problem of water and gas coning in a well in which the interval open to production is located within the sand body, above the static water level and below the static gas-oil interface. In such a case the sand should be divided into two parts and each part treated by the procedure outlined above. The basis for location of the horizontal dividing plane in the sand is that the potential over the well surface ϕ_w must be the same for both the upper and lower portions. The division is located by a trial and error choice of values from Fig. 4 corrected by Fig. 5. Solution is greatly facilitated by a plot of the corresponding

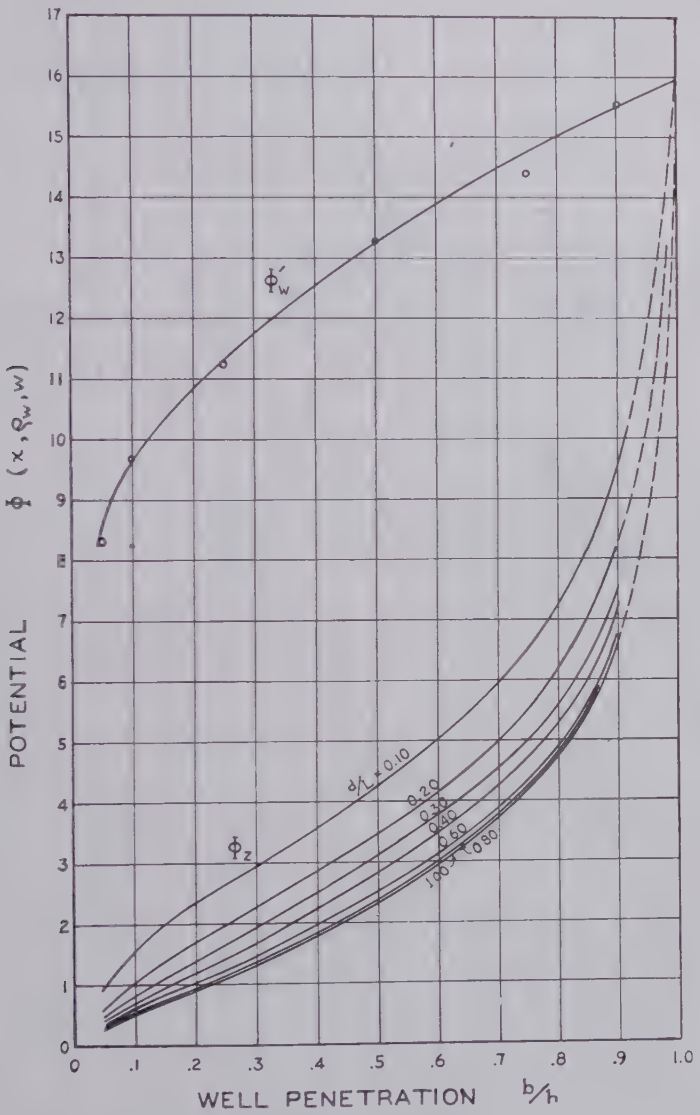

FIG. 4.—VELOCITY POTENTIAL DISTRIBUTION AT WELL RADIUS.

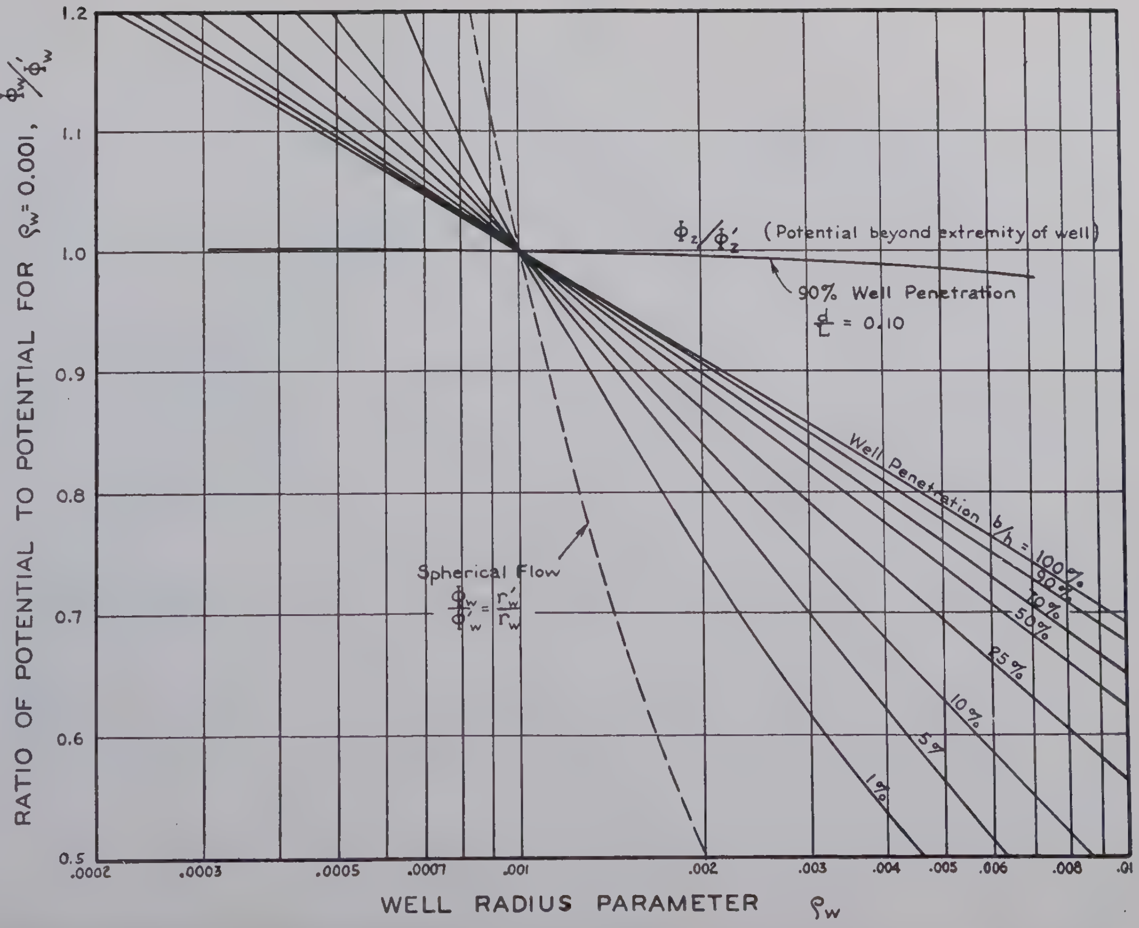

FIG. 5.—CORRECTION FACTORS FOR CONVERTING WELL VELOCITY POTENTIAL OF FIG. 4 TO VELOCITY POTENTIAL FOR OTHER WELL RADII.

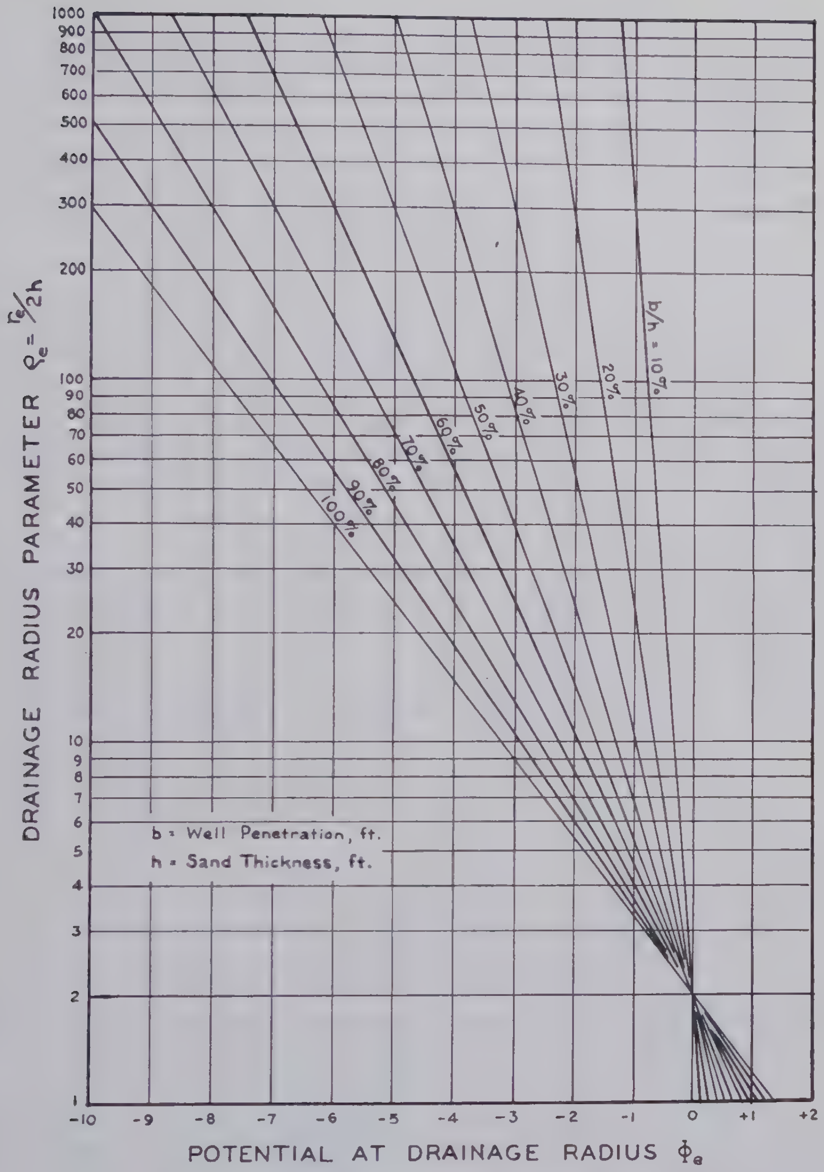

FIG. 6.—VELOCITY POTENTIAL AT DRAINAGE RADIUS.

values of well potential for each portion of the sand against the distance of the dividing plane from an arbitrary datum.

Location of the dividing plane is shown by Fig. 7. The values of ϕ_{w_T} (well potential in top portion) and ϕ_{w_B} (well potential in bottom portion), which are functions of corresponding values of penetration and well-radius parameter, are plotted against the distance of the dividing plane from the gas-oil interface. The intersection of the curves indicates that the correct location of the division is 125.35 ft. below the gas-oil interface and that the potential at the well is 12.14. The calculation of one set of points follows:

Take the dividing plane to be 125.3 ft. below gas-oil interface.

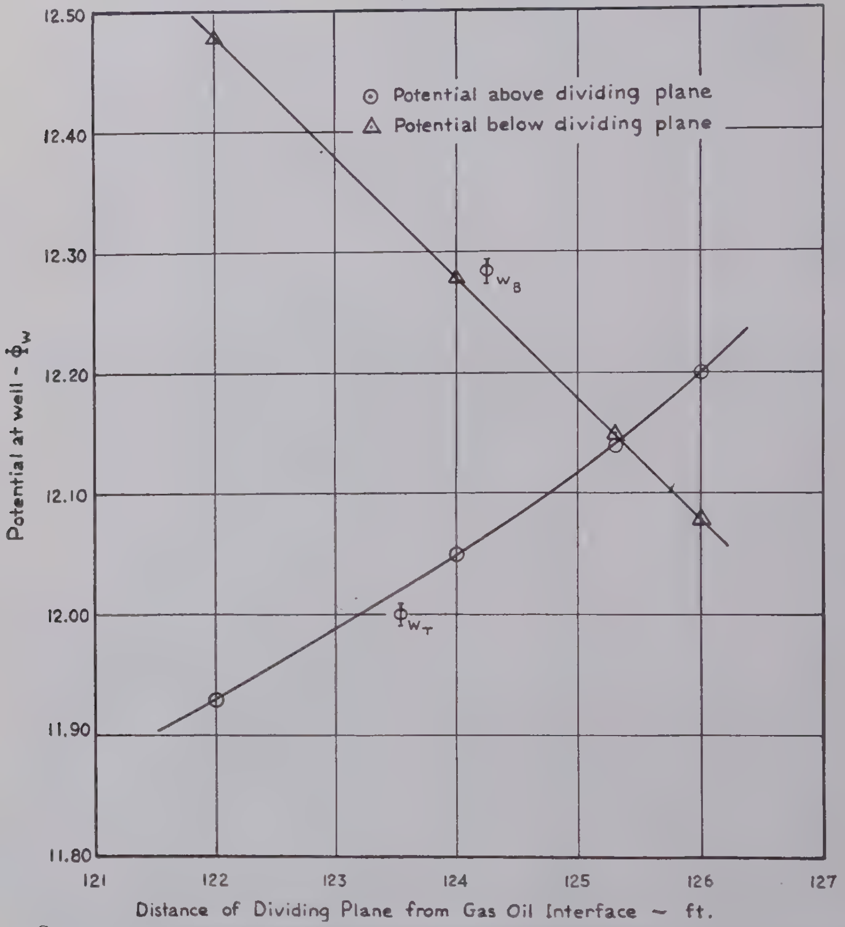

FIG. 7.—SOLUTION OF LOCATION OF DIVIDING PLANE AND VELOCITY POTENTIAL OVER WELL SURFACE FOR CASE OF SIMULTANEOUS CONING OF WATER AND GAS.

EXAMPLE

Depth of gas-oil interface, ft.	7535
Depth of oil-water interface, ft.	7695
Top of perforations, ft.	7623
Bottom of perforations, ft.	7685
Size of liner = 5 in. Radius	0.2083 ft.
Oil gradient in well, lb. per sq. in. per ft.	0.325
Water gradient in well, lb. per sq. in. per ft.	0.425
Gas gradient in well, lb. per sq. in. per ft.	0.085

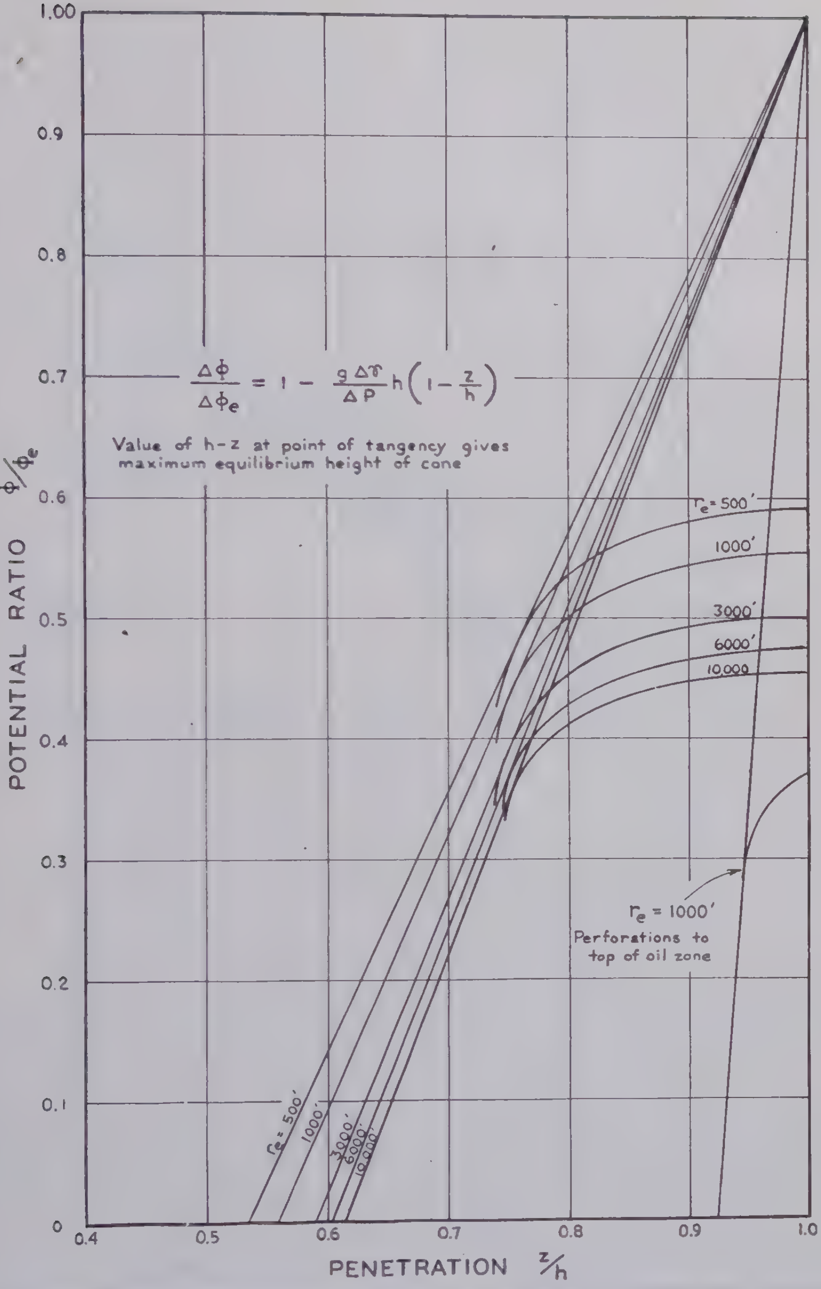

FIG. 8.—EXAMPLE OF GRAPHICAL SOLUTION OF EQUILIBRIUM HEIGHT OF WATER CONE AND MAXIMUM PRESSURE DRAWDOWN WITHOUT WATER CONING, FOR SELECTED VALUES OF DRAINAGE RADIUS.

$$\rho_{wT} = \frac{r_w}{2h_T} = \frac{0.2083}{2 \times 125.3} = 0.000831$$

$$\text{Penetration} = \frac{b_T}{h_T} = \frac{125.3 - 88.0}{125.3}$$
$$= 29.75 \text{ per cent}$$

Water Coning

$h = 34.65$ ft., $b = 24.65$ ft., penetration $= 71.1$ per cent

$\phi_w = 12.14$

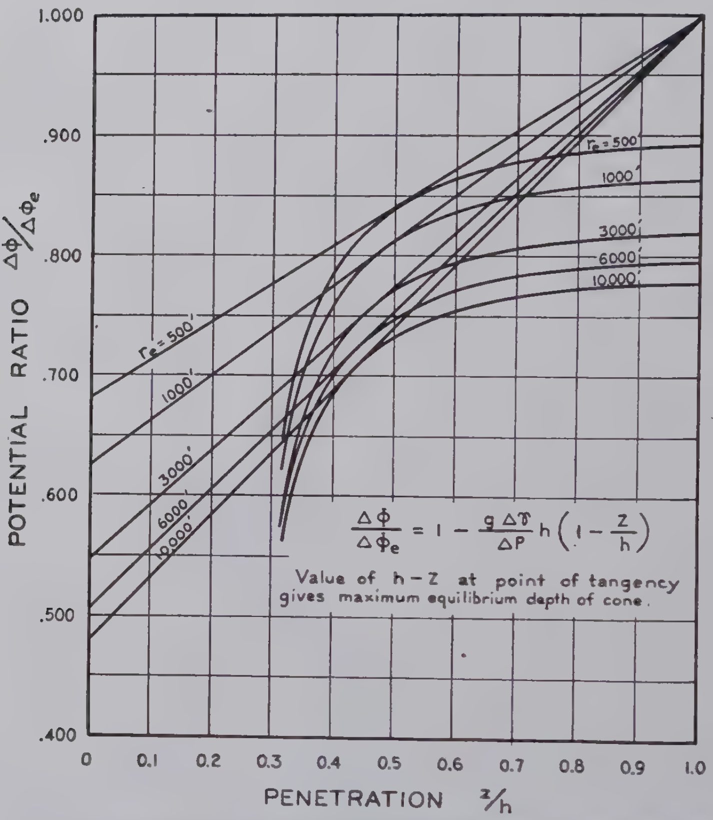

FIG. 9.—EXAMPLE OF GRAPHICAL SOLUTION OF EQUILIBRIUM DEPTH OF GAS CONE AND MAXIMUM PRESSURE DRAWDOWN WITHOUT GAS CONING, FOR SELECTED VALUES OF DRAINAGE RADIUS.

$\phi'_{wT} = 11.75$ for $\rho_w = 0.001$ (from Fig. 4)

$C = 1.033$ (from Fig. 5)

$\phi_{wT} = C\phi'_{wT} = 12.14$

$$\rho_{wB} = \frac{r_w}{2h_B} = \frac{0.2083}{2(160 - 125.3)} = 0.00300$$

$$\frac{b_B}{h_B} = \frac{34.7 - 10.0}{34.7} = 71.2 \text{ per cent}$$

$\phi'_{wB} = 14.54$ for $\rho_w = 0.001$ (from Fig. 4)

$C = 0.836$ (from Fig. 5)

$\phi_{wB} = C\phi'_{wB} = 14.54 \times 0.836 = 12.15$

Chosen values of $\frac{z}{h}$ are expressed in terms of $\frac{d}{L}$ in order to evaluate ϕ_s from Fig. 1.

$$\left(\frac{d}{L} = \frac{\frac{z}{h}h - b}{h - b}\right)$$

Values of $\frac{\phi_w - \phi_z}{\phi_w - \phi_e} = \frac{\Delta\phi}{\Delta\phi_e}$ vs. $\frac{z}{h}$ are determined for various values of drainage radius and are presented in Fig. 8. The maximum allowable pressure drawdown without water coning is calculated from Eq. 21, in which:

$$g\,\Delta\gamma = 0.425 - 0.325 = 0.10 \text{ lb. per sq. in. per ft.}$$

$\left(\frac{\Delta\phi}{\Delta\phi_e}\right)_{\frac{z}{h}=0}$ is calculated from the slope of the tangent in Fig. 8 for the particular value of drainage radius.

Fig. 10 presents the variation of maximum pressure drawdown with drainage radius for the given example. The low values of drawdown pressure that would result in water coning are caused by the drilling of the well to a point only 10 ft. above the oil-water interface in the sand. Failure of these relationships to hold in such cases can be traced to the fact that fingering-type water entry occurs rather than coning, owing to ineffective vertical permeability in the sand over appreciable vertical distance.

The maximum drawdown without water coming for the example may be compared

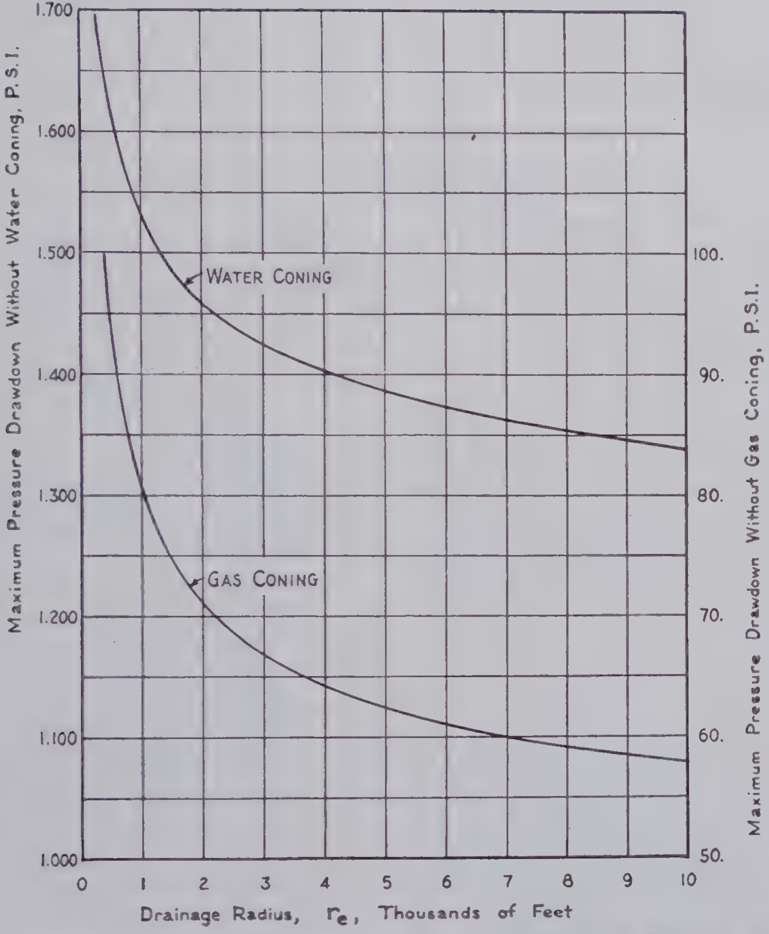

FIG. 10.—EXAMPLE OF MAXIMUM PRESSURE DRAWDOWN WITHOUT CONING OF WATER AND GAS AS FUNCTION OF DRAINAGE RADIUS.

with the corresponding value, if the perforations extended up to the gas-oil interface. Although the constants in the evaluation are entirely different, as may be seen in Fig. 8, it would seem logical that the values of drawdown without water coning would be of the same order of magnitude for each case. For a drainage radius of 1000 ft., the maximum drawdown is 1.2 lb. per sq. in. for the case of perforations extending to the top of the productive oil sand, and 1.5 for the actual conditions of the well chosen as an example.

Gas Coning

$h = 125.35$ ft., $b = 37.35$ ft., penetration = 29.8 per cent

$\phi_w = 12.14$

Values of $\frac{\Delta\phi}{\Delta\phi_e}$ as a function of $\frac{z}{h}$ as determined from Figs. 4 and 5 are presented in Fig. 9 for various values of drainage radius. The variation of maximum drawdown without gas coning as a function of drainage radius for the example is included in Fig. 10.

CONCLUSIONS

The problem of water fingering from a static edge water, updip into a producing oil well in a homogeneous sand, can be solved by application of Eqs. 12 and 15. Drainage radius often is the least known quantity. It can be determined from the drawdown pressures and structural positions that cause water fingering. Water and gas coning in homogeneous sand can be determined by graphical solution of Eq. 16, which was developed by Muskat,[1] by the use of charts provided in this paper.

In homogeneous sand, where permeability is uniform in vertical and horizontal directions, the distance of the well from the static interface of the two fluids is very important. Fingering and coning occur with decreasingly small drawdowns as the distance shortens between the well and the fingering or coning fluid. In nonhomogeneous sand, coning is greatly restricted by small lenses of relatively low permeability directly below the bottom of the well, since these small lenses greatly distort the potential gradients in the sand.

ACKNOWLEDGMENTS

The author appreciates the permission of the Union Oil Company of California to publish this paper and especially thanks E. C. Babson for many suggestions and contributions. Thanks are also due to Jan Law for his review and criticism.

NOMENCLATURE

Q = volume rate of flow.
k = permeability.
r = radius, ft.
h = sand thickness, ft.
μ = viscosity.
ϕ = potential (velocity potential).
P = pressure, lb. per sq. in.
Δ_P = pressure drawdown of producing well, lb. per sq. in.
γ_0 = density of oil.
$\Delta\gamma$ = difference in density between two fluids.
g = acceleration of gravity.
z = distance of point from selected datum level, ft.
t = vertical distance of well from static water level, ft.
θ = angle of dip of sand body, degrees.
y = height of cone above the datum represented by the static interface of the two fluids, ft.
ϕ_w = potential at well surface.
ϕ_w' = potential at well surface for $\rho_w = 0.001$.
ϕ_z = potential at well radius and at depth z.
ϕ_e = potential at drainage radius.
b = penetration of well in sand, ft.
x = penetration parameter $= \frac{b}{2h}$
w = depth parameter $= \frac{z}{2h}$
ρ = radius parameter $= \frac{r}{2h}$.
q = flux density = 1.
ln = natural logarithm.
C = correction of ϕ_w' for value of ρ_w other than 0.001.
d = distance from end of perforated interval of well to point z, ft.
L = distance from end of perforated interval of well to static interface of the two fluids, ft.
$g\Delta\gamma$ = difference in hydrostatic gradient at reservoir conditions between the two fluids involved, lb. per sq. in. per ft.

$\Gamma(n)$ = gamma function defined by

$$\Gamma(n) = \int_0^\infty x^{n-1} e^{-x}\, dx = \int_0^1 \left(\ln \frac{1}{x}\right)^{-1}$$

Tables of the gamma function are given in Dwight.[3]

$\zeta(s, y)$ = zeta function of Riemann[1,2] defined by

$$\zeta(s, y) = \sum_0^\infty \frac{1}{(n + y)^s}$$

Subscripts

w = at well surface.
z = at point in sand.
e = at drainage radius.
T = above horizontal dividing plane in sand.
B = below horizontal dividing plane in sand.

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1. M. Muskat: The Flow of Homogeneous Fluids through Porous Media. New York, 1937. McGraw-Hill Book Co.
2. Whittaker and Watson: Modern Analysis, Ed. 4. Cambridge Univ. Press, 1927.
3. H. B. Dwight: Tables of Integrals and Other Mathematical Data. New York 1934. Macmillan.

APPENDIX

Consider the development of the equations for water fingering. The conditions are illustrated by Fig. 1 and are described in the body of the report. The rate of flow may be expressed by the following equation:

$$Q = \frac{2\pi k r h}{\mu} \frac{d\phi}{dr} \qquad [1]$$

where

$$\phi = P - \gamma_0 g z$$

The significance of the velocity potential ϕ has been discussed. The flow is expressed in terms of velocity potential rather than directly in terms of pressure because the direction of flow is not horizontal and the gravitational gradient must be considered. Separating variables in Eq. 1, and integrating between the limits of well radius and any greater radius gives:

$$\Delta\phi = \phi - \phi_w = \frac{\mu Q}{2\pi k h} \ln \frac{r}{r_w} \qquad [2]$$

From consideration of horizontal radial flow, the following relationship exists:

$$\Delta P = \frac{\mu Q}{2\pi k h} \ln \frac{r}{r_w} \qquad [3]$$

Although the flow is not horizontal, it is two-dimensional if the well completely penetrates the sand, since the fluid motion is identically the same in parallel planes. Furthermore, the static and flowing pressures whose difference constitutes ΔP, the pressure drawdown, are both measured at the same point; namely, the bore of the well. Consequently the factor of gravitational gradient between a point at the well bore and a point at radius r has been eliminated. For these reasons P as well as ϕ will satisfy the La Place differential equation of potential theory.

In order for the water finger to be stable, it is necessary that the pressure gradient at the top of the water surface equal the differential gravitational force between the water and the oil.

$$\phi = \phi_e - \Delta\gamma g \left(t - \frac{dz}{dr} r\right)$$

$$\Delta\phi = \Delta P - \Delta\gamma g \left(t - \frac{dz}{dr} r\right)$$

$$\Delta\phi = \Delta P - \Delta\gamma g y \qquad [4]$$

The quantity y represents the vertical height of the water finger above the static water level. Substitution of relationships expressed by Eqs. 2 and 3 gives

$$\frac{\mu Q}{2\pi k h} \ln \frac{r}{r_w} = \Delta P - \Delta\gamma g y \qquad [5]$$

The quantity $\frac{\mu Q}{2\pi k h}$, which is constant for any given set of conditions, may be evaluated at r equal to the drainage radius, the distance from the well at which the static or shut-in pressure of the well exists during flowing conditions, by the following form of Eq. 3:

$$\frac{\mu Q}{2\pi k h} = \frac{\Delta P}{\ln \frac{r_e}{r_w}} \qquad [6]$$

Therefore Eq. 5 may be rewritten:

$$\frac{\Delta P}{\ln \frac{r_e}{r_w}} \ln \frac{r}{r_w} = \Delta P - \Delta \gamma g y \qquad [7]$$

The equation of the surface of the water cusp is expressed by:

$$y = t - r \sin \theta = \frac{\Delta P}{\Delta \gamma g}\left(1 - \frac{\ln \frac{r}{r_w}}{\ln \frac{r_e}{r_w}}\right) \qquad [8]$$

The limit of approach of the water finger to the well without exceeding the condition of stability can be determined. Fingers of water approaching closer than this limit will be drawn into the well. The potential gradient set up from fluid flow may be represented by

$$\frac{d\phi}{dr} = \frac{\mu Q}{2\pi k h r} \qquad [9]$$

Substitution of the relationship expressed by Eq. 6 gives

$$\frac{d\phi}{dr} = \frac{\Delta P}{\ln \frac{r_e}{r_w}} \frac{1}{r} \qquad [10]$$

and the potential gradient set up by the differential gravitational forces between the oil and water is given by

$$\frac{d\phi}{dr} = \Delta \gamma g \frac{dz}{dr} = \Delta \gamma g \sin \theta \qquad [11]$$

Simultaneous solution of the two preceding equations for r gives the minimum distance a finger can approach without being drawn into the well by an unstable condition:

$$r_{\min} = \frac{\Delta P}{\Delta \gamma g \sin \theta \ln \frac{r_e}{r_w}} \qquad [12]$$

From geometric considerations,

$$y = t - r \sin \theta \qquad [13]$$

By substitution of Eq. 12 for $r_{\min}$,

$$y_{\max} = t_{\min} - \frac{\Delta P}{\Delta \gamma g \ln \frac{r_e}{r_w}} \qquad [14]$$

Equating this to the general equation for y (Eq. 8), and solving for t gives

$$t_{\min} = \frac{\Delta P}{\Delta \gamma g}\left(\frac{1 + \ln \frac{r_e}{r_{\min}}}{\ln \frac{r_e}{r_w}}\right) \qquad [15]$$

The example cited in the body of the report illustrates application of water fingering in a homogeneous sand that has the geometric conditions shown by Fig. 1.

In coning of water or gas into a well that partially penetrates a homogeneous oil sand as illustrated by Fig. 3, the relation of the potential forces set up from the fluid flowing in the sand to the differential gravitational forces between the fluids involved is shown by Muskat[1] to be

$$\frac{\Delta \phi}{\Delta \phi_e} = \frac{\phi_w - \phi_z}{\phi_w - \phi_e} = 1 - \frac{g \Delta \gamma}{\Delta P} h \left(1 - \frac{z}{h}\right) \qquad [16]$$

Equations expressing the velocity potentials deserve some explanation. Muskat has derived the following expression for the value of the potential over a sand in which there is a partially penetrating producing well. The expression is valid for small values of the radius parameter,

$$\begin{aligned} \phi = q \Big\{ & - \ln \frac{\Gamma(1 + w + x)\Gamma(1 - w + x)}{\Gamma(1 - w - x)\Gamma(1 + w - x)} \\ & + \ln \frac{w + x + [\rho^2 + (w + x)^2]^{1/2}}{w - x + [\rho^2 + (w - x)^2]^{1/2}} \\ & - \frac{1}{4}\rho^2[\zeta(2, 1 - w - x) - \zeta(2, 1 - w + x) \\ & + \zeta(2, 1 + w - x) - \zeta(2, 1 + w + x)] \\ & + o(\rho^4) \Big\} \end{aligned} \qquad [17]$$

The last term drops out because the coefficient is zero. The term involving ρ^2 is negligible for the range of values encountered. Eq. 17 is derived for a well of infinitely small radius. However, it does not conform to the requirements that the potential is uniform over the well surface. In order to satisfy this condition for a well of finite radius, the flux density q is not taken to be uniform over the well surface. It is adjusted to values over finite increments of length of the well that will enable a uniform potential to be obtained over the surface of the well. Fig. 80 of Muskat[1] shows the adjusted and unadjusted values given by Eq. 17. Fig. 4 of this paper is a cross plot of the adjusted values presented graphically by Muskat. Muskat indicates that the actual well potential may be taken to be proportional to the value obtained from Eq. 17, using a uniform flux density q and setting $w = 3/4 x$.

Fig. 4 is based on a particular well-radius parameter $\rho_w = 0.001$, or $r_w = 0.002h$. In order to correct the values given by Fig. 4 for potential at the well-bore radius to values of well-bore radius other than $\rho_w = 0.001$, Eq. 17 was evaluated for different values of the variables and with $w = 3/4 x$. It was assumed that the variation of the adjusted well potential with well radius is proportional to the variation of the unadjusted values of potential. The variation of ϕ_s with ρ_w was found to be negligible except for points very close to the well. Well-bore correction factors to be applied to the value of well potential ϕ_w' from Fig. 4 are presented in Fig. 5. Variation of ϕ_s is also included in Fig. 5 for the extreme case of 90 per cent well penetration and at a point 10 per cent into the oil sand beyond the extremity of the well.

For large values of the radius parameter, the value of the potential in the sand is given by Muskat to be

$$\phi = 4q\left[\frac{1}{\pi}\sum_{n=1}^{n=\infty}\frac{1}{n}K_0(2n\pi\rho)\cos(2n\pi w)\sin(2n\pi w) + x\ln\frac{2}{\rho}\right] \quad [18]$$

K_0 is the Hankel function or Bessel function of zero order and modified second kind (sometimes called the third kind). A detailed discussion of Bessel functions is given by Whittaker and Watson.[2] For large values of the argument X, the following asymptotic expansion is given for K_0 by Dwight:[3]

$$K_0(X) \simeq \left(\frac{\pi}{2X}\right)^{1/2} e^{-X}\left[1 - \frac{1^2}{1!8X} + \frac{1^2\cdot 3^2}{2!(8X)^2} - \frac{1^2\cdot 3^2\cdot 5^2}{3!(8X)^3} + \cdots\right] \quad [19]$$

Since the value of the argument $X = 2n\pi\rho$ is large, the value of the function K_0 is neglibibly small for practical values of drainage radius. For ρ equal to or greater than one, Eq. 18 may be written

$$\phi = 4qx\ln\frac{2}{\rho} \quad [20]$$

Eq. 20 is the basis for the values of ϕ_s presented in Fig. 6.

DISCUSSION

N. van Wingen,* Los Angeles, Calif.—This paper presents an interesting application of mathematical concepts developed by M. Muskat. Because of the complexity of the problem, the mathematics are of necessity involved and although treatment is facilitated by means of Mr. Arthur's charts, a considerable knowledge of advanced mathematics continues to be necessary in order to follow through adequately the various steps of the analysis. As such, the paper presents a formidable obstacle to the average engineer.

In regard to the practical value of the results to be obtained by this method, it is apparent that the simplifying assumptions, which, of necessity, have to be made as yet for the analytical treatment of a problem of this nature, may in certain areas severely limit the quantitative usefulness of the data. For example, it seems doubtful whether any productive zone in California could meet the required prerequisite of homogeneity and yet be sufficiently massive to permit the selective perforation of but a portion of the productive sand to yield a commercially productive well. Likewise, inability to discern small lenses of low-permeability sand directly below the bottom of the well in an otherwise homogeneous sand body would result, as the author points out, in the well being perforated unnecessarily high. This will not only cause a loss in well potential but may well result also in the obtainment of a lesser ultimate recovery due to by-passing of the encroaching water. One other point suggests itself, and that is that the permissible well drawdown to prevent fingering and coning will decrease continuously as water encroaches with the depletion of the oil reserve, or in the event of an expanding gas cap. This again may mean that well rates may soon become uneconomic.

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* Senior Production Engineer, Richfield Oil Corporation.

These comments are not offered to distract in any manner from the value of this excellent paper, but merely to emphasize again that extreme caution has to be exercised in applying analytical methods to actual oil-field problems. It is to be hoped that work of this nature will continue to be pursued intensively, so that ultimately we may perhaps learn to evaluate specifically the effects of the various complicating factors that now have to be ruled out from the consideration as being too complex to lend themselves to mathematical treatment.

W. T. Lietz,* Los Angeles, Calif.—I consider Mr. Arthur's paper a valuable contribution to the theoretical background of water and gas coning. In the application of the results of this theoretical analysis, the following points may need some further investigation. It appears from the mathematical development that the maximum height to which a water cone can be drawn up without entering the well is independent of the permeability of the rock, viscosities of the fluids and relative permeabilities of the rock after replacement of one fluid by another.

The only factors appearing in the formulas are slope of formation, distance of well from edge water and difference in density of fluids.

This result would seem logical, since the author considers the time that the cone has reached its maximum height and is therefore stationary. However, when one considers the period in which the cone is formed, the situation is somewhat different.

The rate of advancement of the cone is a function of the relationship between the viscosities of the fluids and relative permeability. During the time the cone is formed, oil is produced from the well, causing a general rise of the water table, and conditions may prevent stable conditions from ever being reached. It would be interesting to make some investigations for different known viscosities and relative permeabilities of the effect of the delay in the formation of the water cone.

In a water drive, the oil is produced as a result of the replacement of oil by water. For a maximum recovery of oil, it is essential that the washing action in the area, invaded by the water, is as complete as possible, and that the volume of the reservoir, invaded by the water, is a maximum at the time the well reaches its economic limit. The mathematical development in the paper deals only with static conditions, and it would be interesting to see an analysis of the effect of the rate of production on the efficiency of replacement and the size and shape of the reservoir invaded by water at the time the well is abandoned.

These investigations would seem necessary for an interpretation of the mathematical developments of the paper. The numerical example shows that for a development with 600 ft. radius (±30 acres per well) the allowable drawdown is very small, so that, unless permeabilities are extremely high, the rate of production would be so small that in some cases the well would reach its economic limit before the cone has been formed, owing to the decline in productivity index observed in many reservoirs.

These considerations apply also to the case of water and gas coning discussed in the second part of the paper.

M. G. Arthur (author's reply).—Since it was realized that the mathematics involved in a development of the problem are a formidable obstacle to many engineers, the paper presented attempted to indicate the relative effect of the various variables to those who would accept the validity of the mathematical development.

Some California oil fields having high permeability and low standard deviations of permeability[4] are sufficiently homogeneous for coning to occur. However, most California fields have relatively low effective permeability at right angles to the bedding planes and the fingering type of water encroachment is commoner than coning.

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* Shell Oil Company.

In fields where there is evidence that coning may occur, intervals of low permeability such as shale lenses may be located by electric logs or by cores, and if such a break is at a convenient point the well may be plugged to this point before the liner is run, or cemented blank liner may be perforated above this point. If vertical permeability is such that coning can occur, little oil will be lost ultimately because the level of the bottom water probably will rise, flushing oil out of the sand below the shale lens at which the well was bottomed. If the water table fails to rise, the interval below the shale lens may be perforated as a salvage operation late in the life of the field, at which time drawdowns will be low and adequate dehydration facilities probably will have been constructed to handle the production.

Where water encroaches the oil reservoir with depletion, it is unavoidable that production rates without coning will eventually become uneconomic. The solution would be to accept the production of water with the oil or to prevent it by plugging back the wells. It is hoped that consideration of the relationships presented in the paper will aid in determining the extent of these operations.

In primary and secondary water drive the objective is not to prevent water encroachment but to prevent undue fingering of the advancing water front. For edge water advancing at a relatively constant rate in a homogeneous sand, the relationships presented in the paper will determine the lead that a finger or cone can have on the advancing front. If the general encroachment is so rapid that stable conditions cannot be attained, fingering and coning will be of less magnitude than shown by the paper.

The effect of rate of production on efficiency of replacement or washing action is a dynamic problem of a nature different from coning and fingering. It must be attacked from an entirely different approach, which would involve many more variables than those considered in this paper.

The solution of the problem of preventing unreasonably low drawdowns without water coning is to stay some distance away from the static edge-water position. The allowable pressure drawdowns increase exponentially with increasing distance of the well from static edge-water position. In the numerical example of water coning presented, uneconomical rates of production would be required in order to prevent water coning. The alternatives would be to accept production of water with the oil or to plug back the well to a greater distance from the bottom water.

In regard to well density, the spacing is not a good measure of the drainage radius. Drainage radius very often is greater than the distance between wells.

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[4] J. Law: A Statistical Approach to Interstitial Heterogeneity of Sand Reservoirs. This volume, page 202.

A Statistical Approach to the Interstitial Heterogeneity of Sand Reservoirs

BY JAN LAW,* JUNIOR MEMBER A.I.M.E.

(Los Angeles Meeting, October 1943)

PROBLEMS of oil recovery are attacked from the approaches dictated by the two strikingly dissimilar complexes that comprise an oil reservoir—the fluid complex and the interstitial complex. Knowledge of the fluid complex, due to labors in the fields of fluid mechanics and physical chemistry, has far outdistanced knowledge of the interstitial characteristics of the sand complex. This paper is concerned with the latter and applies the technique of statistics to petrographic facts—namely, porosity and permeability—dealing with what might be called petrometry.

Statisticians have long worked within the problem of reconstruction of a universe of variables by means of samples that comprise a small percentage of the universe from which the samples were drawn. Core-analysis data comply with the requisite of random sampling as stipulated by theoretical statistics. A basic concept of statistics employs the following substitution:

1. The results of sampling are arranged as a frequency distribution.
2. The observed frequency distribution is compared with a mathematically precise distribution.
3. If a sufficiently good agreement is found between the two, the precise distribution is substituted in all subsequent operations involving characteristics of the sampled material.

This mathematically precise distribution is also known as the normal curve, curve of error, the probability, the Gaussian, and the bell-shaped curve and is describable with but two figures. Further, these two figures, the arithmetic average and the standard deviation, are subject to mathematical manipulation.

This paper demonstrates that, in some cases in the Dominguez field of Southern California, if sufficient core-analysis samples are taken over not too great a thickness of sediments, the resultant permeability and porosity assemblages give satisfactory agreement with normal curves.

It is shown that the indications are strong that oil wells wherein a satisfactory agreement is found are predictable as to productivity. Since the predictions are made by employing the laws of chance that are operative within sedimentation, it follows that the mechanism by which the predictions were made is a basic concept of reservoir mechanics. Therefore, tentative examples are given of the application of normal curves to the solution of problems of primary and secondary recovery.

NATURE OF PERMEABILITY FREQUENCY DISTRIBUTIONS

Core-analysis data are made available as a tabulated depth vs. permeability profile. The nature of the distribution of permeability values within a given stratigraphic interval may be approximated from an array constructed with samples plotted in the order of their appearance with depth (accession number) against their permeability value in millidarcys.

A wide variation in the nature of the distribution of *K* (permeability) values for

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* Dominguez Oil Fields Co., Compton, Calif.

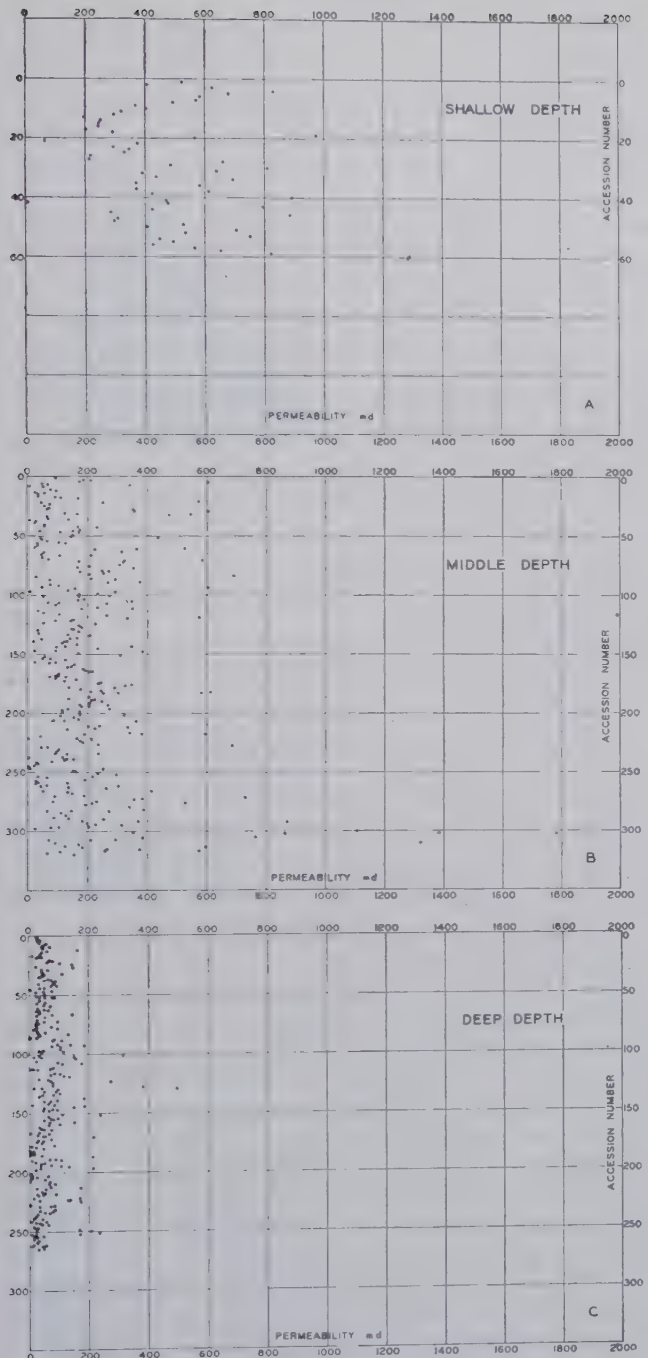

FIG. 1.—ARITHMETIC PERMEABILITY ARRAY.

a shallow, a middle depth, and a deep interval is shown in Fig. 1.

The qualitative measure of distribution available by inspection from these figures is available quantitatively from a tabulation of K by class intervals (Table 1).

TABLE 1.—*Example of Arithmetic Frequency Distribution in Shallow Zone*

	Class Limits, Millidarcys					
	100–300	300–500	500–700	700–900	900–1100	
	292	370	523	799	975	
	191	320	585	707	937	
	251	377	575	756		
	248	346	565	832		
	241	353	558	810		
	203	390	530	888		
	294	370	539	883		
	294	370	568	824		
	217	305	625			
	214	407	680			
	282	497	660			
	299	402	640			
		484	696			
		439	615			
		425	650			
		466				
		477				
		426				
		403				
		447				
		498				
		424				
Totals........	12	22	15	8	2	59
Percentages...	20.34	37.29	25.42	13.56	3.39	100

Comparable tabulations and percentages were obtained for the three intervals and plotted as frequency distributions in Fig. 2.

The frequency distributions as shown in Fig. 2 are asymmetrical about the central class or, in statistical language, skewed to the right. Mathematical manipulation of badly skewed curves is unsatisfactory. Also, it was found necessary to vary the class interval from zone to zone in order to obtain curves that reveal the distribution. This variation of class interval renders direct mathematical comparison zone to zone impossible.

An array constructed on the basis of accession number vs. the logarithims of K gives a symmetrical distribution of values about a central trend of greatest density of points, as shown in Fig. 3.

A frequency distribution that would be symmetrical can be derived from this array by laying off equally spaced intervals across the K scale, such as ½ in. or 1 in., and counting the number of times that K values fall within the individual limits laid down.

Such a procedure would be difficult to standardize. The author proposes a mathematical expression to standardize this operation, which was suggested by Krumbein.[1] The expression relates the logarithm of K to the size of the class interval.

Tests were made to determine the applicability of class intervals that result from the expressions:

$$\phi = \mathrm{Log}_{\sqrt{2.5}} \frac{K}{10}$$

$$\phi = \mathrm{Log}_{\sqrt{2}} \frac{K}{10}$$

$$\phi = \mathrm{Log}_{2} \frac{K}{10}$$

Phi in these cases is merely a scale value. The $\log_{\sqrt{2}}$ was found to give the most symmetrical curves and was then used to accumulate K values in new class intervals as shown in Table 2.

The percentages derived from Table 2 were calculated for the three intervals and Figs. *A*, *B* and *C* of Fig. 4 were constructed by tying the percentage values together with straight dashed lines.

Since there are chance variations attributable to sampling, it is desired to determine the approximation of this sampled distribution to a pure probability distribution.

The values that describe the sampled distribution were calculated and are shown in Table 3. The ordinates of the normal curve that has the same values of X_ϕ and σ_ϕ as the observed curve as calculated are shown in Table 4. π_{ϕ_3} and α_{ϕ_4} being small are considered to represent the amount of variation due to sampling—not characteristics of the distribution of the material from which the samples were taken.

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[1] References are at the end of the paper.

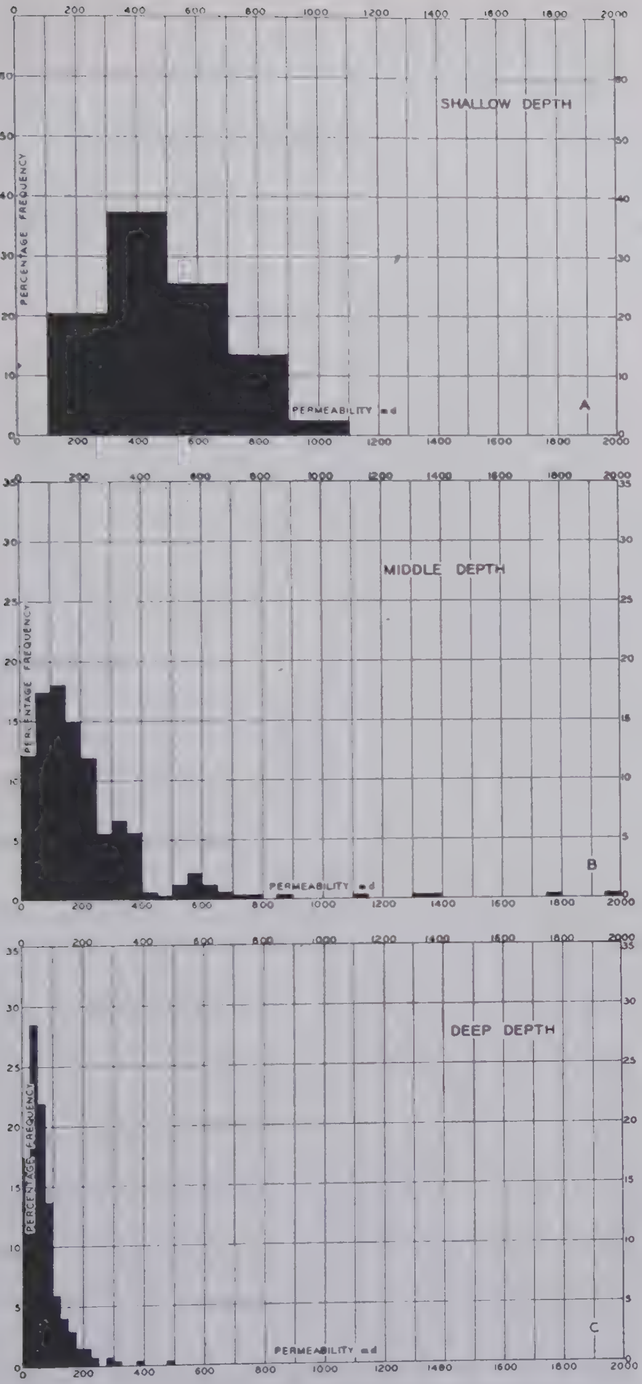

FIG. 2.—ARITHMETIC PERMEABILITY HISTOGRAM.

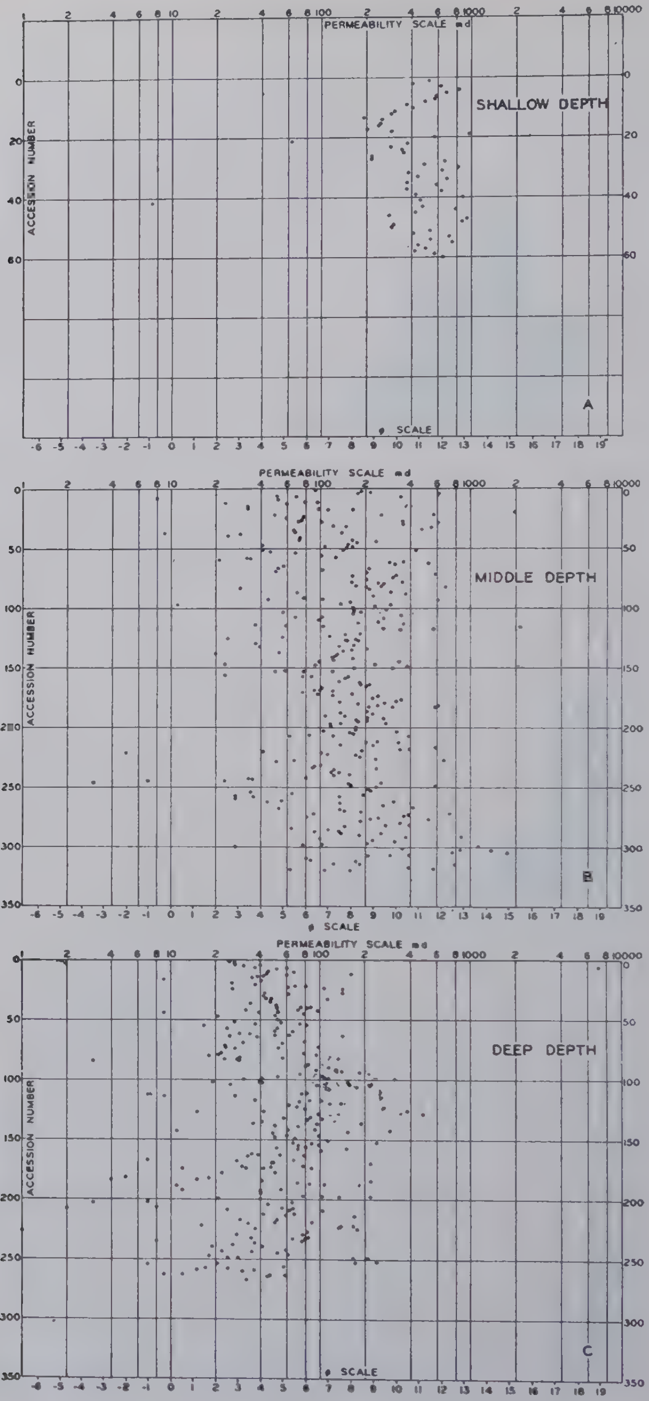

FIG. 3.—LOGARITHMIC PERMEABILITY ARRAY.

The solid-line curves of Fig. 4 were obtained by joining with a smooth line the ordinate heights calculated in Table 4.

TABLE 2.—*Example of Logarithmic Frequency Distribution in Shallow Zone*

Class Limits

Phi scale	8–9	9–10	10–11	11–12	12–13	13–14	
Millidarcy scale	160–224	224–320	320–448	448–640	640–896	896–1280	
	191	202	407	523	832	975	
	203	251	370	625	680	937	
	217	248	402	585	660		
	214	241	320	575	810		
		294	377	497	696		
		294	346	565	888		
		282	353	484	799		
		305	390	640	883		
		299	439	558	707		
			370	615	756		
			425	477	650		
			426	530	824		
			403	539			
			447	498			
			424	568			
			370	466			
Totals	4	9	16	16	12	2	59
Percentages	6.78	15.25	27.12	27.12	20.34	3.39	100.00
Accumulated percentages	6.78	22.03	49.15	76.27	96.61	100.00	

A test was then made to determine the chances that the distribution of the material being sampled is normal.

Areas under the normal curve were computed and compared with areas under the sampled curve by means of the chi-squared test for goodness of fit. These computations are given in Tables 5 and 6.

TABLE 3.—*Example of Calculation of Distribution Characteristics by Moment Method, Shallow Zone*

PER CENT

Phi Class Limits	f	d	fd	d^2	fd^2	d^3	fd^3	d^4	fd^4
8–9	6.78	−2	−13.56	4	27.12	−8	−54.24	16	108.48
9–10	15.25	−1	−15.25	1	15.25	−1	−15.25	1	15.25
10–11	27.12	0	0.00	0	0.00	0	0.00	0	0.00
11–12	27.12	+1	+27.12	1	27.12	+1	+27.12	1	27.12
12–13	20.34	+2	+40.68	4	81.36	+8	+162.72	16	325.44
13–14	3.39	+3	+10.17	9	30.51	+27	+91.53	81	274.59
Algebraic totals			+49.16		+181.36		+211.88		+750.88

$V_1 = +0.49 \quad \pi_1 = 0 \quad X_\phi = 10.5 + 0.49 = 10.99$

$V_2 = +1.81 \quad \pi_2 = 1.57 \quad \sigma_\phi = (1.57)^{1/2} = 1.25$

$V_3 = +2.12 \quad \pi_3 = -0.422 \quad \pi_{3\phi} = -0.422$

$V_4 = +7.51 \quad \pi_4 = +5.79 \quad \alpha_{4\phi} = +1.77$

$V_1, V_2 \ldots V_4$ to $\pi_1, \pi_2 \ldots \pi_4$ is translation of axis.

X_ϕ is the arithmetic mean in phi, or the abscissa value of the center of gravity of the curve.

σ_ϕ is the standard deviation in phi, or the radius of gyration of the distribution about a vertical axis through the center of gravity.

$\left.\begin{matrix}\pi_{3\phi}\\ \alpha_{4\phi}\end{matrix}\right\}$ are, respectively, in phi, the absolute skewness and the relative kurtosis and are derived from the third and fourth moments of the distribution.

The answer to this test is given in terms of probability P. For this example, if the material being sampled had a normal distribution, 40 times out of 100 as poor a fit or worse than that obtained would have occurred, because of the chance variations attributable to sampling.

Hence hereafter a substitution of the normal curve for the observed curve is made for all operations involving the distribution of permeability in the interval.

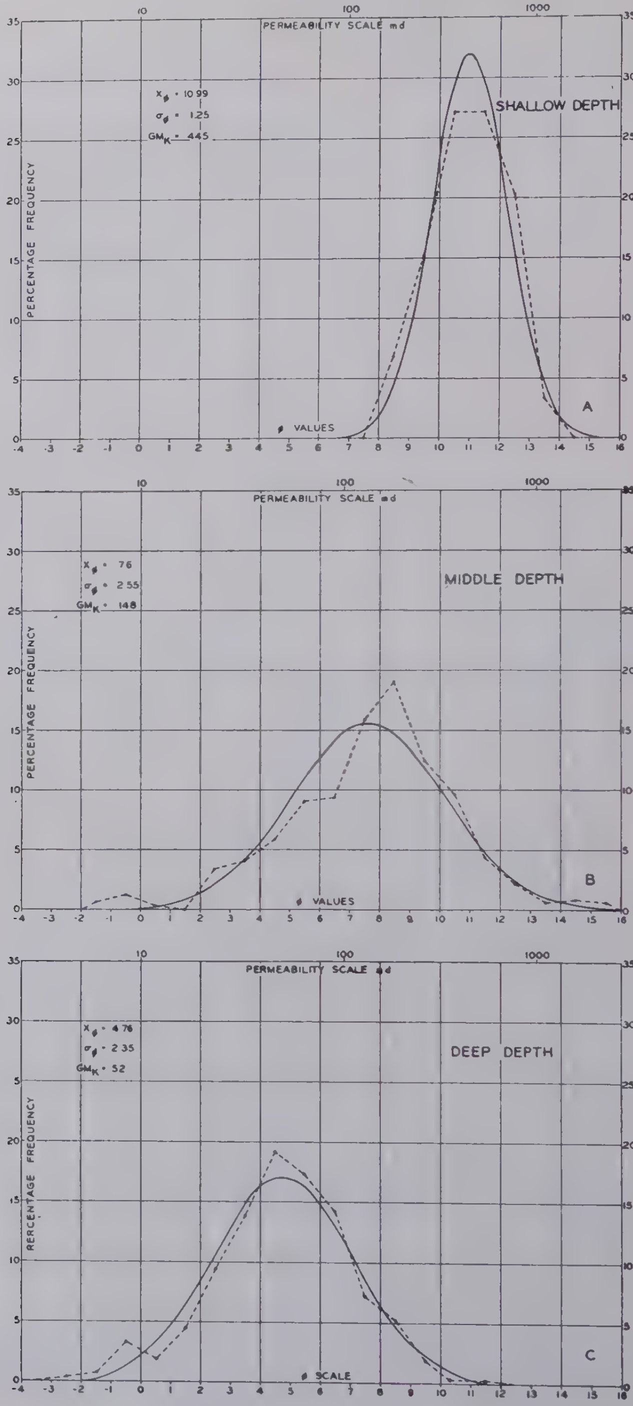

FIG. 4.—LOGARITHMIC PERMEABILITY DISTRIBUTION.

From a petrographic sense a precise mathematical measure of the magnitude and spread of permeability values is available.

TABLE 4.—*Example of Calculation of Fitted Curve, Shallow Zone*
$X_\phi = 11.00$ and $\sigma_\phi = 1.25$

Limit Phi	X	$\frac{X}{\sigma_\phi}$	$-\frac{X^2}{e^2\sigma^2}$	Ordinate Height
6	5	4.00	0.0003	0.01
7	4	3.20	0.006	0.19
8	3	2.40	0.056	1.78
9	2	1.60	0.278	8.90
10	1	0.80	0.726	23.20
11	0	0.00	1.000	32.00
12	1	0.80	0.726	23.20
13	2	1.60	0.278	8.90
14	3	2.40	0.056	1.78
15	4	3.20	0.006	0.19
16	5	4.00	0.0003	0.01

$$Y_0 = \frac{100}{\sigma\sqrt{2\pi}} e^{-\frac{X^2}{2\sigma^2}} = 32.00 \text{ where } X = 0$$

A rapid method is available for the determination of X_ϕ and σ_ϕ and to determine approximately the fit obtained. The procedure is described by Otto.[2] The percentages determined in the calculation of the phi frequency distribution are accumulated and plotted on arithmetic probability paper. The results are shown in Fig. 5.

TABLE 5.—*Example of Calculations of Areas under the Normal Curve, Shallow Zone*

Phi		X	$\frac{X}{\sigma}$	Per Cent Area[a]	Per Cent Area in Class	Observed Per Cent Area
Lower Limits	Upper Limits					
6		5	4.00	0.4999	0.06	0.00
7		4	3.20	0.4993	0.75	0.00
8		3	2.40	0.4918	4.66	6.78
9		2	1.60	0.4452	15.71	15.25
10		1	0.80	0.2881	28.81	27.12
11		0	0.00			
	12	1	0.80	0.2881	28.81	27.12
	13	2	1.60	0.4452	15.71	20.34
	14	3	2.40	0.4918	4.66	3.39
	15	4	3.20	0.4993	0.75	0.00
	16	5	4.00	0.4999	0.06	0.00

[a] Per cent area $= \int_0^X \frac{100}{\sigma\sqrt{2\pi}} e^{-\frac{X^2}{2\sigma^2}}$

The intercept of the line drawn between the 15.9 per cent and the 84.1 per cent values of the curve and the 50 per cent line is the arithmetic average in phi.

The arithmetic average in phi subtracted from the 84.1 per cent value is the σ_ϕ.

Departures of the observed curve from the line joining the 84.1 per cent and the 15.9 per cent intercepts and its prolongation indicate the approximate amount of skewness and kurtosis present in the observed data. If the departures are sufficient, caution is indicated in the use of the normal curve to describe the observed assemblage.

TABLE 6.—*Examples of Chi-squared Test for Goodness of Fit, Shallow Zone*

Limits	Observed f	Calculated fc	$f - fc$	$(f - fc)^2$	$\frac{(f - fc)^2}{fc}$
6–7	0.00	0.06			
7–8	0.00	0.75	+1.31	1.72	0.38
8–9	6.78	4.66			
9–10	15.25	15.71	−0.46	0.21	0.13
10–11	27.12	28.81	−1.69	2.85	0.10
11–12	27.12	28.81	−1.69	2.85	0.10
12–13	20.34	15.71	+4.63	21.40	1.36
13–14	3.39	4.66			
14–15	0.00	0.75	−2.08	4.31	0.92
15–16	0.00	0.06			
Total..					2.99

Chi-squared = 2.99
$N = 6 - 3 = 3$
$P =$ = 0.40

A Demonstration, That Oil Wells Perform in Accordance with Their Permeability Distributions

In dealing with permeability, one is dealing with the resistance to the flow of fluids in the rock. If the composite effect of the numerous scattered values of permeability encountered in a well can be evaluated, oil-well performance can be put on a rational basis.

The most direct proof that intervals are describable in terms of a normal distribution of K lies in the prediction of initial productivity.

An attempt was made to predict initial productivity by the following procedure:

1. The Norris Johnston[3] adaptation of the Pyle-Sherborne[4] curve of specific productivity index vs. permeability was set at

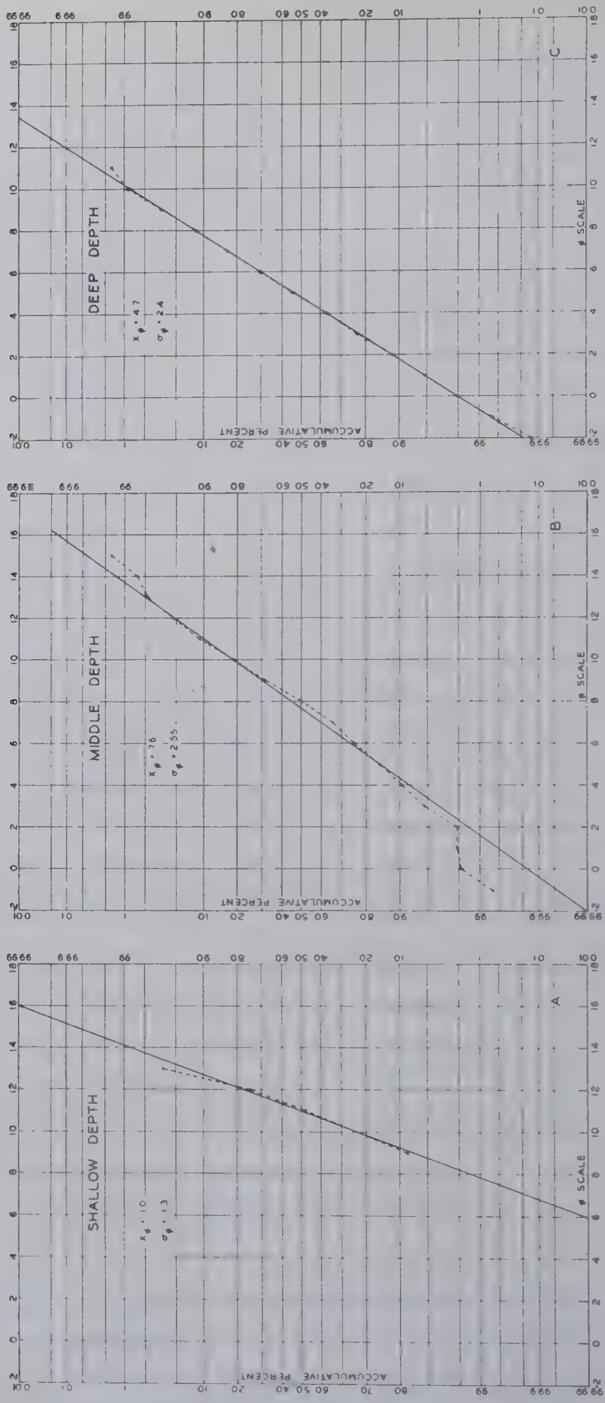

FIG. 5.—ARITHMETIC PROBABILITY PLOTS OF PERMEABILITY DISTRIBUTION.

TABLE 7.—*Type Calculation of Specific Productivity Index*
$X_\phi = 5$ and $\sigma_\phi = 1$

Class Limits	f, Per Cent	Mid-point Sp. P.I.	P.I. (for 100 Ft. Sand)	Productivity Index	
				Per Cent	Accumulated, Per Cent
1–2	0.13	0.00037	0.000048		
2–3	2.14	0.00067	0.001430	0.4	0.4
3–4	13.60	0.00118	0.016100	4.5	4.9
4–5	34.13	0.00210	0.072000	20.0	24.9
5–6	34.13	0.00410	0.140000	38.7	63.6
6–7	13.60	0.00740	0.101000	28.0	91.6
7–8	2.14	0.01300	0.027800	7.5	99.1
8–9	0.13	0.02500	0.003250	0.9	100.0
Totals. . . .			0.361638	100.0	
Sp. P.I.			0.0036		

Variation of Specific Productivity Index with σ_ϕ

X_ϕ	σ_ϕ	Sp. P.I.	Increase, Per Cent
5	0	0.0031	0
5	1	0.0036	16
5	2	0.0062	100
5	3	0.0132	325

a slope of 2 and shifted to higher values of specific productivity index for equivalent *K* values. The curve was adopted because it was felt that it expressed correctly the effect of increasing values of permeability but was inadequate to express the spread of permeability encountered. The shift was necessitated because entry is made in these predictions with the geometric average permeability, which is always below that of the arithmetic average. The amount of shift was governed by trial and error, using one well as a criterion.

The next three steps are illustrated in Table 7.

2. The mid-point value of each phi class was determined in terms of equivalent specific productivity index.

3. Percentages under the curve between class limits were determined for a set of normal curves of which X_ϕ was held constant and σ_ϕ varied between 1 and 3. This process was repeated for other values of X_ϕ.

4. The resultant areas were multiplied by their corresponding specific productivity index values, the resultant productivity indexes added and divided by 100.

5. The results of such computations, together with the curve of specific productivity index vs. permeability, were plotted on Fig. 6.

6. Twelve wells in a single zone at Dominguez were employed for a test of predictability. Their permeability values were gathered in phi, percentages taken, and accumulated. From a plot of these percentages on arithmetic-probability paper

TABLE 8.—*Tabulation of Prediction of Productivity of Twelve Wells*

Well No.	X_ϕ	σ_ϕ	Completion Pressure as Per Cent Initial Pressure	First Approx. Sp. P.I.	Produced Sp. P.I.	Produced Sp. P.I. as Percentage of First Approx. Sp. P.I.	Predicted Sp. P.I.
T- 1	4.7	2.3	89	0.0053	0.0067	126	0.0066
T- 2	4.86	3.23	89	0.0160	0.0193	120	0.0190
T- 3	6.42	2.05	97	0.0128	0.0142	114	0.0224
T- 4	2.2	2.4	77	0.0015	0.0015	100	0.0010
T- 5	5.4	2.25	75	0.0081	0.0036	44	0.0048
T- 6	4.0	2.25	75	0.0036	0.0029	57	0.0022
T- 7	2.4	3.10	52	0.0033	0.0007	21	0.00065
T- 8[a]	5.75	1.65	83	0.0075	0.0015	20	0.0057
T- 9	6.6	2.2	55	0.0185	0.0035	19	0.0042
T-10[a]	2.6	3.1	63	0.00325	0.0002	6	0.0011
T-11	5.8	2.75	72	0.0117	0.0062	53	0.0062
T-12	5.5	2.2	50	0.0095	0.0016	17	0.0017

[a] Cemented liners, gun perforated.

the X_ϕ and σ_ϕ (Table 8) for each well determined.

With these values in hand, the specific productivity indexes of the wells were computed graphically from Fig. 6.

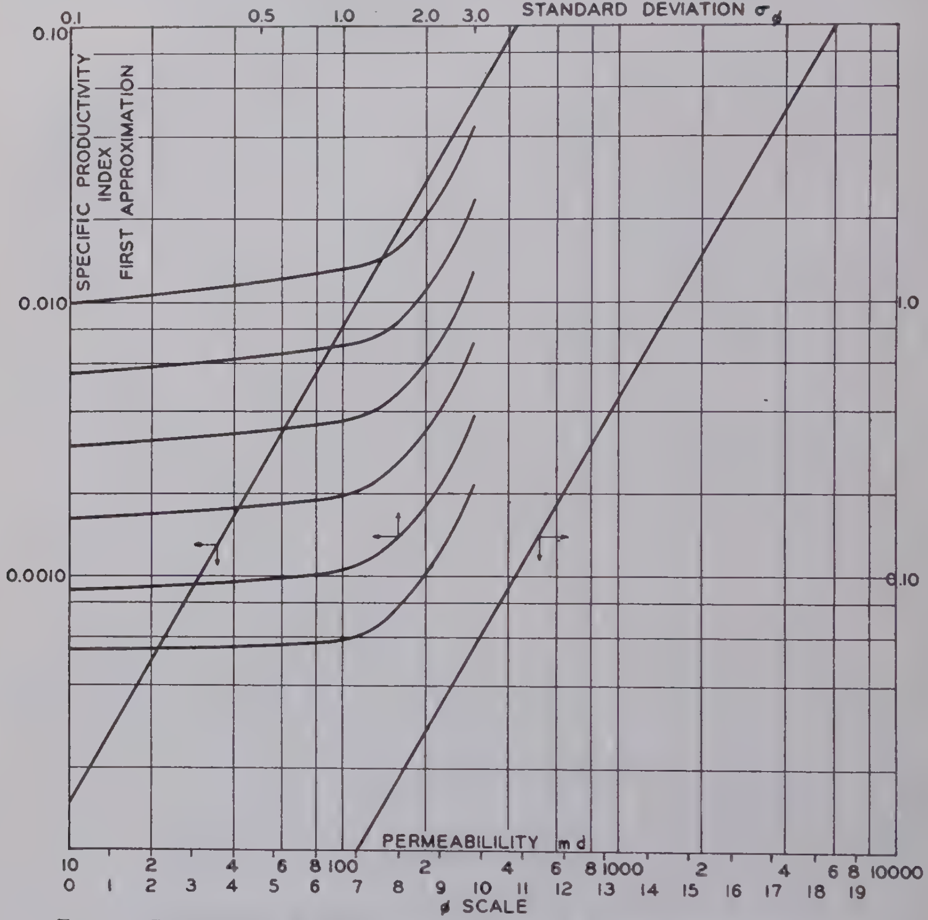

Fig. 6.—Calculation of first approximation of specific productivity index.

7. The computed specific productivity indexes were compared with the measured initial values. The measured values were seen to fall below the computed values as successively larger well numbers were encountered. Since the wells were drilled in the order of their numbers, it followed that successively lower formation pressures were being encountered with each new completion. Standard works on saturation and formation viscosities indicate that the effective permeability should decrease as the zone pressure is decreased and experience is common that productivity indexes do so decrease in practice with depletion. Babson[5] has calculated a theoretical decline in productivity index as a function of recovery and has obtained an approximately straight line.

8. Therefore a plot was made of the measured initial specific productivity indexes expressed as a percentage of the calculated indexes and plotted against the initial well pressure expressed as a percentage of the original zonal pressure. The results are plotted on Fig. 7. Values in excess of 100 per cent of the calculated

specific productivity index presumably result because the well that was used as a criterion to shift the Pyle-Sherborne curve was not completed at original zonal pressure.

9. On Fig. 8 45° lines were laid off through points that represented the intercepts of the even 10 per cent pressure values and their corresponding percentages of specific productivity index from Fig. 7.

10. The calculated indexes by the graphic method of Fig. 6 were entered on the ordinate scale of Fig. 8, moved horizontally across the page until the line of percentage pressure, corresponding to the pressure of the well being determined, was reached, then the value on the abscissa scale was read.

11. The values of specific productivity index read on the abscissa scale, therefore, are the predicted specific productivity indexes for the 12 wells in question.

For comparative purposes, the calculated specific productivity indexes are plotted against the measured initial indexes on Fig. 9. Except for the two wells with cemented liners, the accuracy of prediction is that there is a 6 to 10 chance of a correct answer within ±10 per cent, and a certainty of a correct answer within ±35 per cent. The deviations of the two gun-perforated wells from the trend is in partial accord with Muskat.[6]

Fig. 7 is sufficiently compatible with both theory and oil-field experience, and the mechanism of the increase in specific productivity index with increased σ_ϕ is sufficiently reasonable so that the demonstration is strong that oil wells perform in accordance with their permeability distributions.

EMPLOYMENT OF THE NORMAL DISTRIBUTION OF PERMEABILITY TO PROBLEMS OF RECOVERY

The effectiveness of a gas or water drive is a function of the uniformity of the sands being flushed. The σ_ϕ appears to be the proper criterion of uniformity. If normality is not present, the best sand to flood will approach minimum σ_ϕ, maximum negative $\pi_{3\phi}$ and minimum $\alpha_{4\phi}$.

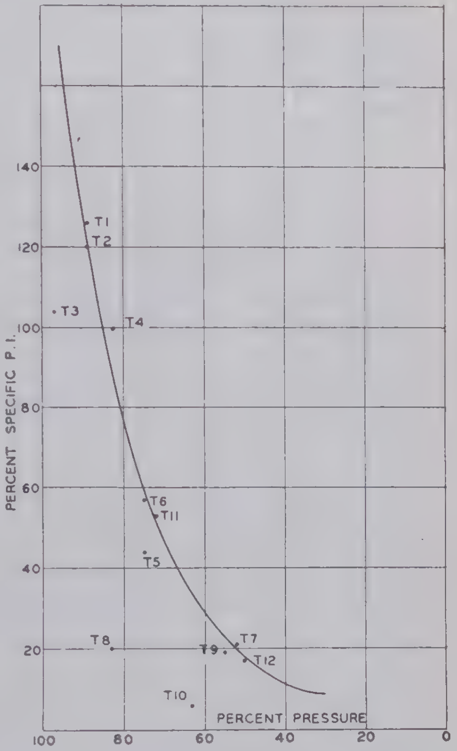

FIG. 7.—EFFECT OF DECREASE IN PRESSURE ON INITIAL PRODUCED SPECIFIC PRODUCTIVITY INDEX.

TABLE 9.—*Type Calculation of Cumulative Per Cent Curve*

$X_\phi = 5$, $\sigma_\phi = 1$ (values from Table No. 7)

Limits		Sand		P.I.	
Phi	Md.	Per Cent	Acc. Per Cent	Per Cent	Acc. Per Cent
1–2	14–20	0.13	0.13	0.0	0.0
2–3	20–28	2.14	2.27	0.4	0.4
3–4	28–40	13.60	15.87	4.5	4.9
4–5	40–56	34.13	50.50	20.0	24.9
5–6	56–80	34.13	84.13	28.7	63.9
6–7	80–112	13.60	97.73	28.0	91.6
7–8	112–160	2.14	99.87	7.5	99.1
8–9	160–224	0.13	100.00	0.9	100.0

The sharply increasing specific productivity indexes of K assemblages as a func-

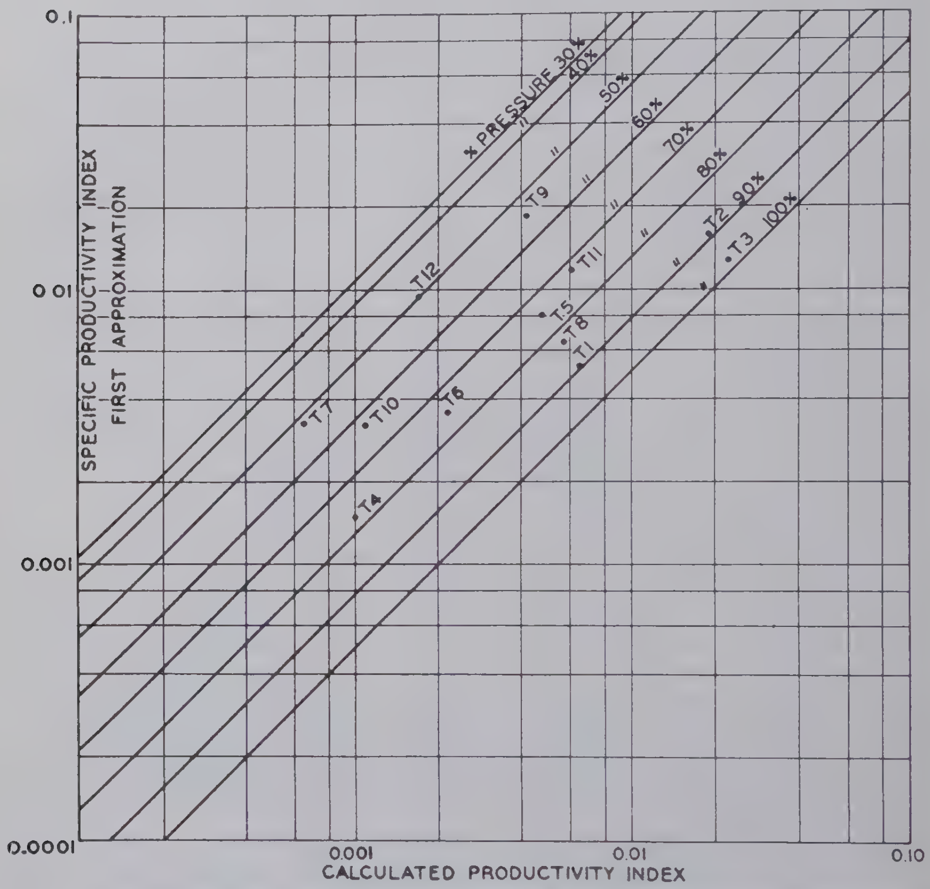

FIG. 8.—GRAPHIC SOLUTION FOR EFFECT OF DECREASE IN PRESSURE OF SPECIFIC PRODUCTIVITY INDEX.

tion of the σ_ϕ indicates that a major portion of the early production of a well comes from a minor portion of the exposed sand.

These proportions may be calculated as is done in Table 9 and displayed for the shallow, middle depth and deep intervals in Fig. 10.

By choosing each even 10 per cent of the sand and following downward lines of constant permeability, the corresponding percentage of productivity index is available. From such operations the curves of Fig. 11 are constructed. These are known as Lorenz curves and are used in economics to show the concentration of production.

Assuming complete horizontal uniformity of permeability, the Lorenz curve depicts schematically the shape of an advancing edge water under conditions of equivalent effective permeability and no interface effect. Expressed quantitatively, if the Lorenz curve shows that 60 per cent of the productivity of a zone comes from 10 per cent of the sand, it follows that in a well close to original edge water that at present has a water cut of 60 per cent, of the total sand exposed 10 per cent has gone to water.

If there is complete horizontal nonuniformity of permeability, the schematic face would be vertical, and under conditions of complete nonuniformity of horizontal permeability, if the well cut is 60 per cent the proportion of sand gone to water is 60 per cent.

If gas or water is injected into a well with a 60 per cent P.I. and 10 per cent sand relationship, 60 per cent of the induced fluid will enter 10 per cent of the sand. This process will be initiated regardless of horizontal variation in permeability. The process will continue until the sand that is permeable at the well bore is packed to the outer reaches of relatively high permeability.

The two postulates; first, that water will enter the well via the sand of highest permeability and, second, that gas in the well bore will also selectively enter the sand of highest permeability, are subject to demonstration by gas injection into a wet well followed by gas withdrawal and return to production.

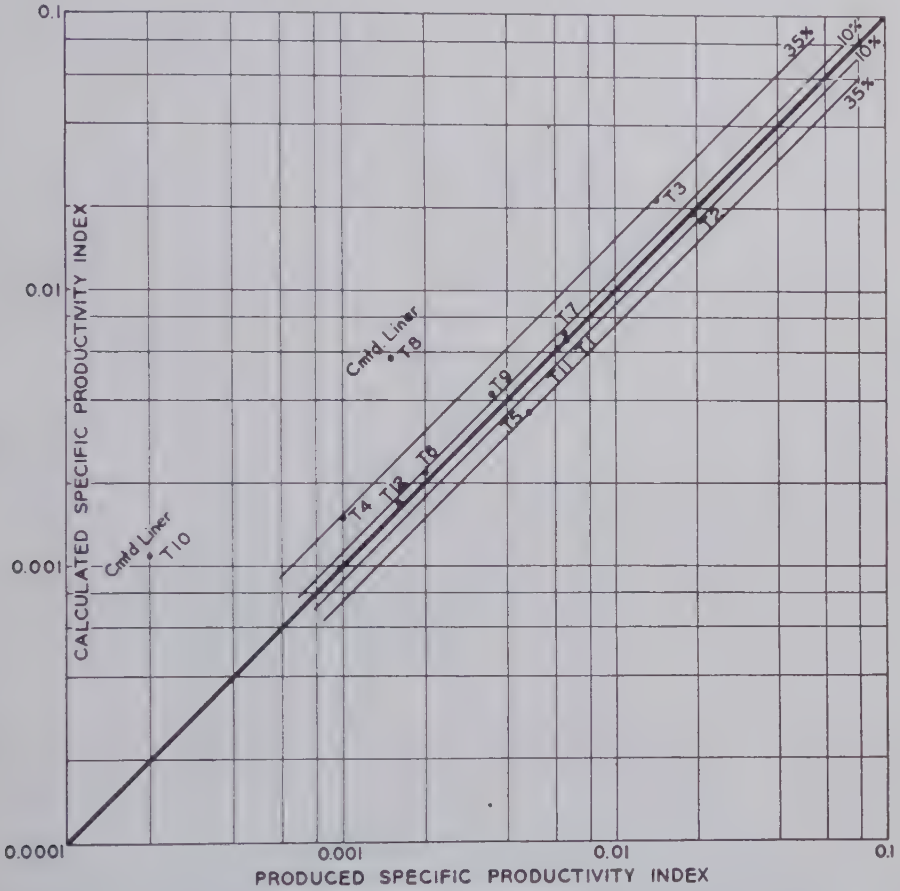

Fig. 9.—Comparative results calculated vs. produced specific productivity index.

Fig. 12 is such an example. The relationship here shown between injected gas and water cut is in accord with the postulates.

A Proposed Method by Which the Degree of Horizontal Uniformity of a Sand Might Be Evaluated

Since individual *K* samples span approximately ¾ in. of vertical distance within the well bore, apparently it is impossible to correlate *K* values well to well as stratigraphic equivalents. If on the other hand a section of sand were sampled every 1 in.

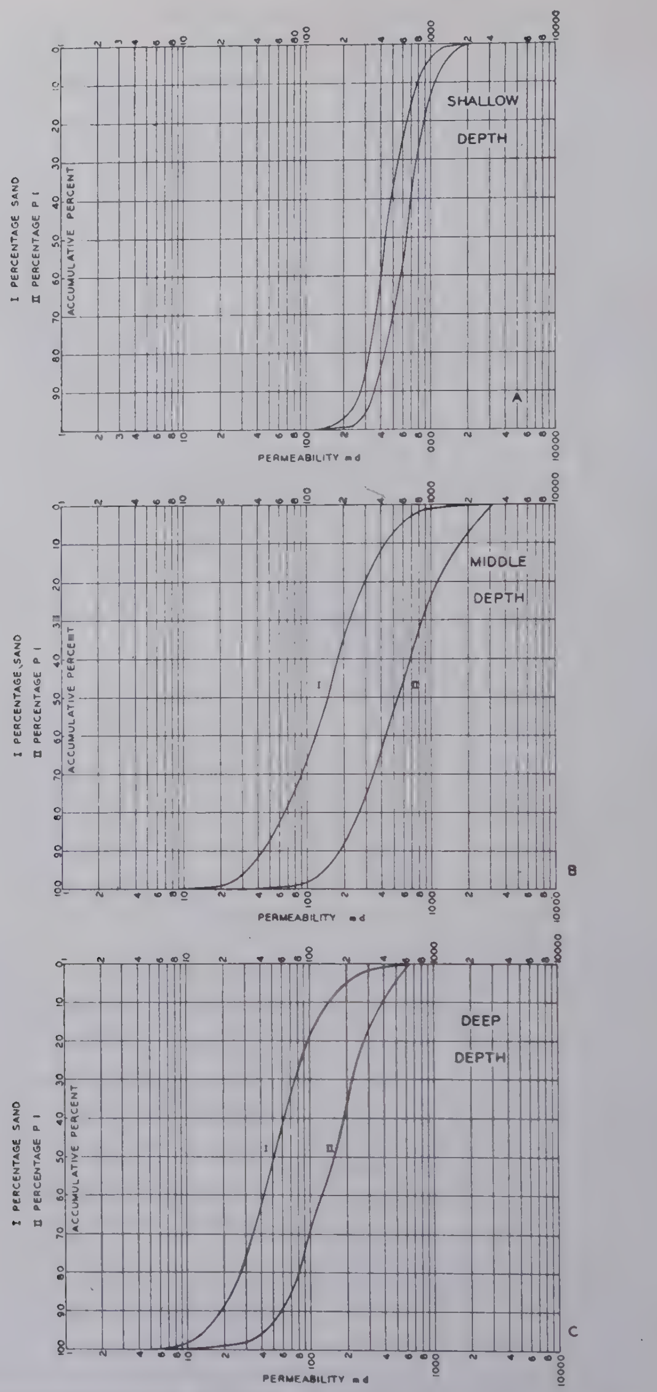

Fig. 10.—Accumulative per cent of sand and productivity index.

and the resultant permeability profile were sufficiently regular to allow interpolation, assurance of proper stratigraphic permeability correlation would be possible.

The permeability profile of Fig. 13 is the result of such a study made on a 4-ft. sand capped and based with shales and containing a 1-in. streak of shale through the center. The profile is sufficiently random so that the validity of interpolation is in doubt. Therefore a screen analysis was made of the *K* samples for stations 24 through 38. The grain-size profile of Fig. 13 resulted.

Since the screen-analysis profile and the permeability profile are similar, and the screen-analysis profile delineates a stable variation in sedimentation, it follows that the amount of interpolation necessary to compare two permeability profiles taken of this stratigraphic interval in two offsetting wells could be made with some assurance.

Until another well is drilled in which all the hazards of acquiring such a comprehensive analysis as performed on the 4-ft. section are met fortuitously, this matter must remain unanswered.

Porosity Distributions

Porosity distributions give symmetrical arithmetic normal curves. The standard deviations encountered by the author show a small range. As seen in Fig. 14, the arithmetic average decreases with depth.

The distributions give a precise affirmation to the use of the arithmetic average of porosity for reservoir calculations.

Porosity-permeability Correlation

The correlation table of Fig. 15 warrants thoughtful consideration. Much that is statistically unsatisfactory is believed to be due to the inability to always take *K* values parallel to bedding and to the measurement of porosity values as total rather than effective.

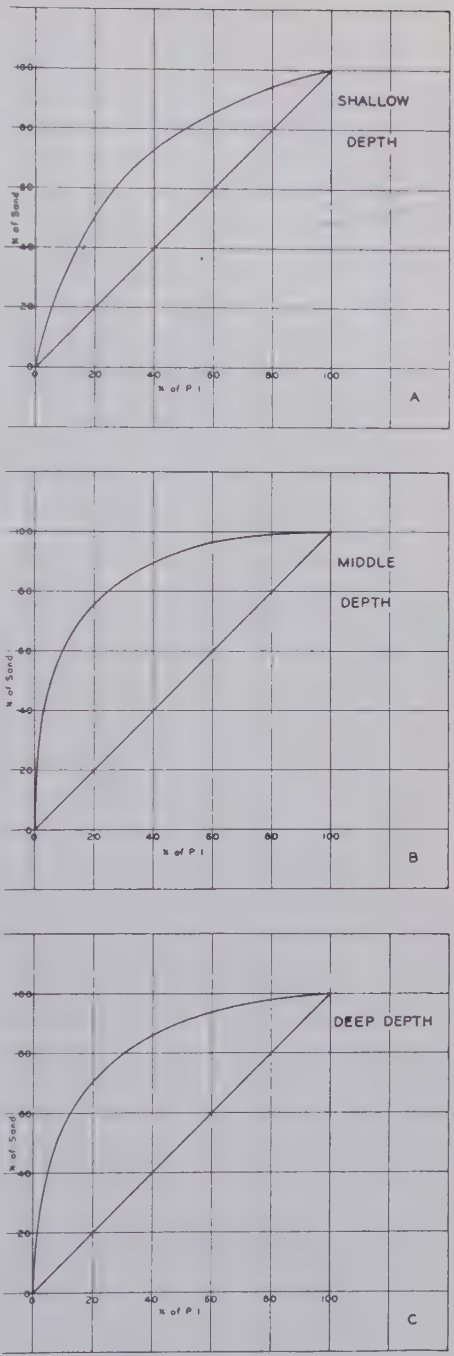

Fig. 11.—Lorenz curve of sand and productivity index.

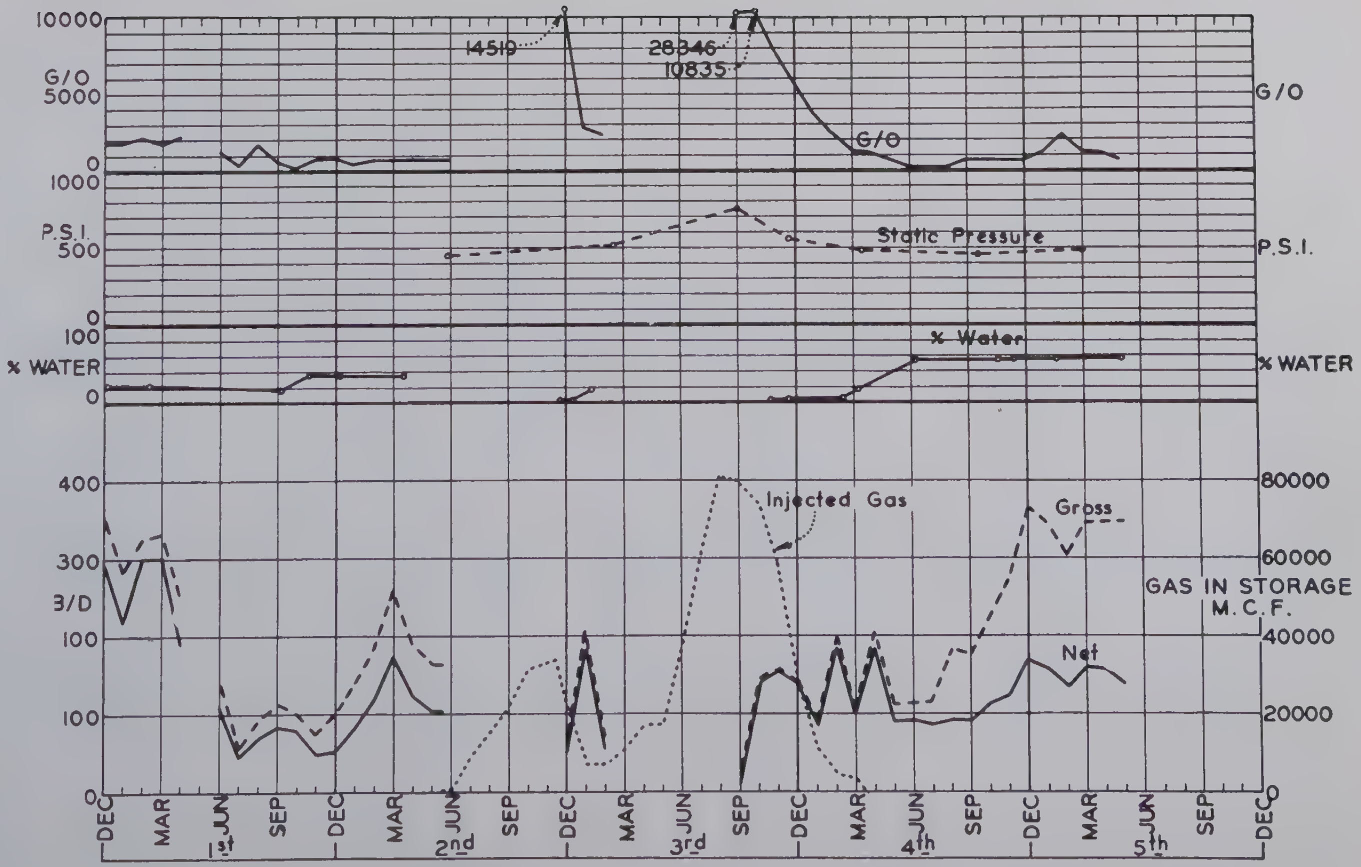

FIG. 12.—EFFECT OF GAS INJECTION ON WATER PRODUCTION.

It is believed that this table presents an approach to interstitical heterogeneity on an intensive basis.

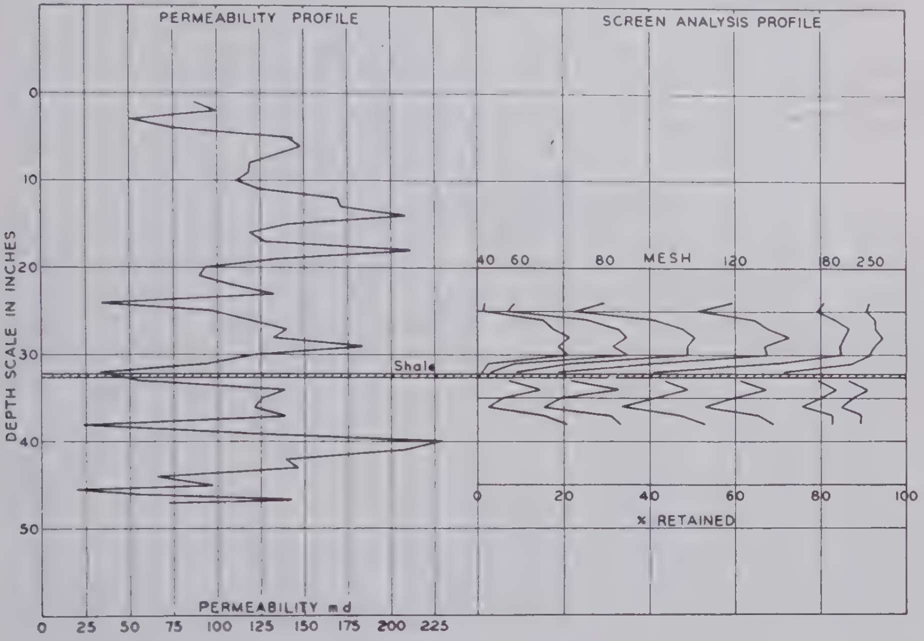

Fig. 13.—Detailed permeability profile.

Conclusions

It has been desired that this paper portray the salient features of distributions. Therefore no space has been given to either the refinements indicated or the features of speculation aroused. The major conclusions to be derived from the data are believed to be:

1. With some exceptions permeability and porosity assemblages give respectively satisfactory logarithmic and arithmetic normal frequency distributions.

2. Statistical technique appears to offer the reservoir analyst opportunities for the solution of oil-field problems.

3. The solution of the problem of the anatomy of sand reservoirs is a problem common to the sedimentary geologist and the reservoir analyst. The recognition of permeability distributions further provides that the efforts of one should complement the other.

Acknowledgments

The author wishes to thank the Dominguez Oil Fields Co. for release of this material; the Union Oil Co. for cooperation in certain phases of this work performed by its core-analysis laboratory outside of routine operations, and the Union Oil Co. and the Shell Oil Co. for release of Dominguez core data.

If this paper is a contribution, it is due to the early faith of H. C. Pyle and J. E. Sherborne that if sufficient core data could be gathered a comprehensive analysis would be forthcoming. If their faith had not been followed by perseverance, the paper could not have been written.

The work of Krumbein on analysis of sand grain size was but slightly altered by the author, and applied to permeability assemblages.

The criticism of E. C. Babson, Milan Arthur, and Roy Wagoner, all of the Union Oil Co., has provided whatever degree of coherency the paper may have attained.

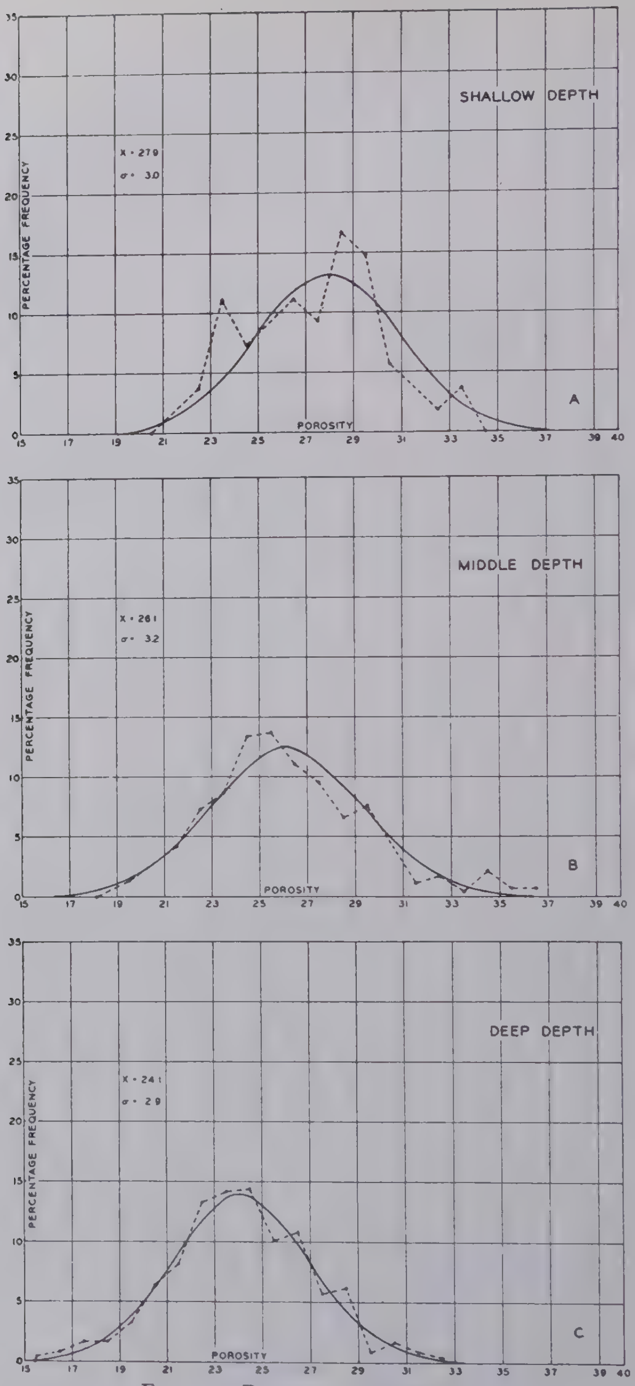

FIG. 14.—POROSITY DISTRIBUTIONS.

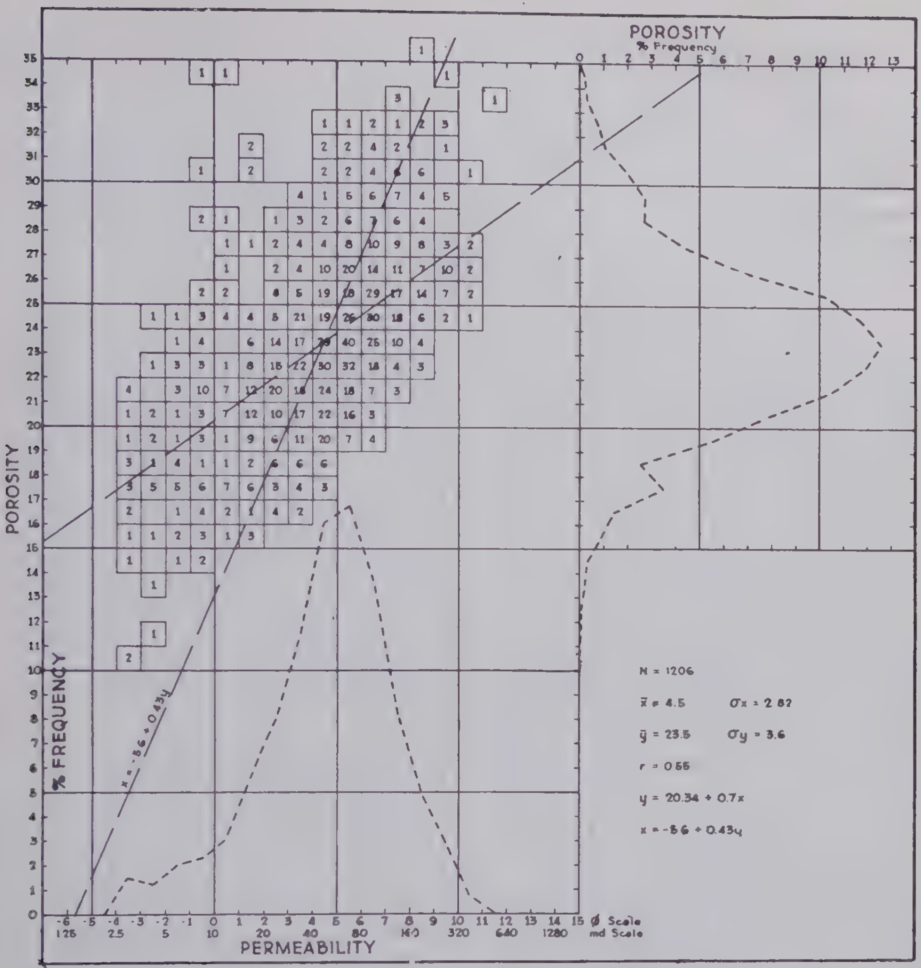

FIG. 15.—POROSITY VS. PERMEABILITY, DEEP INTERVAL.

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DISCUSSION

N. JOHNSTON,* Los Angeles, Calif.—Mr. Law has made a new and useful application of an old and well-known method of analysis. He comes to the conclusion that the graphical relation between permeability and productivity index is subject to an improvement which brings into the picture the deviation of individual permeabilities from the average. I have wanted for some time to make some such refinement, so this is a welcome contribution.

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* Physicist, General Petroleum Corporation of California.

There is another aspect of the averaging of varying permeabilities. When a given sand interval contains permeabilities varying over a wide range, the resultant flow capacity of the interval for a given fluid depends very greatly not only on the statistical but also on the physical distribution of the sand streaks of varying permeability. To illustrate: if in a 20-ft. sand interval, half the sand has a permeability of 10 md., the other half, 100 md., the arithmetic average permeability is 55 md., regardless of the physical distribution. One of the two extreme cases would be represented by two 10-ft. homogeneous strata in contact, one of 10 md., the other of 100 md. permeability. The other extreme would be represented by a regular alternation of thin streaks of sands of the two permeabilities. In the first case, the flow capacity would be approximately equivalent to that of a solid sand interval of uniform permeability of 55 md. In the second case the flow capacity would be equivalent to that of a 20-ft. homogeneous sand body of much higher permeability, possibly 99 md., if the sand streaks were thin enough and permeably connected. This is because the oil or gas in the tight streaks would quickly migrate obliquely into the more permeable sand, and flow into the well along these better conductors, effectively by-passing the tighter streaks.

The phenomenon of oblique flow is mathematically so complex that even Dr. Muskat has been unwilling to tackle it in generalized form, and has published so far only a simple special case. With variations in permeability of 100:1, the proper solution of an extreme case of oblique flow could change well-productivity estimates by as much as 2:1 from the estimate made from a simple arithmetic average. If there is any way in which Mr. Law's statistical analysis can help to give us a solution to the oblique-flow problem, I am sure we should welcome the result. As it stands, Mr. Law's contribution is of considerable value, and, among other things, should lead the way to a better understanding of the deviations of individual wells from the average curve relating specific productivity index to permeability.[1]

J. Law (author's reply).—In this author's opinion, because of the lack of knowledge of the incidence of interstitial heterogeneity, a solution to the problem of oblique flow is not indicated.

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[1] N. Johnston and J. E. Sherborne: Permeability as Related to Productivity Index. Amer. Petr. Inst. Drill. and Prod. Practice (1943).

Selective Acidizing and Permeability Determination by an Electrical Method

By Dana G. Hefley* and P. E. Fitzgerald,* Member A.I.M.E.

(New York Meeting, February 1943)

Abstract

An apparatus has been developed which permits selective acidizing of producing formations and determination of the relative permeability of a formation by fluid injection. This apparatus, known as the "Electric Pilot," is an electrical fluid-interface locator, the electrical circuit of which is completed when the electrodes in the well are in contact with a conductive fluid, but is not completed when immersed in a nonconductive fluid. Results are given for a number of typical acidizing applications in which the interface locator was used to control the acid. Description of the method used in making a permeability survey and the data obtained are also included.

Introduction

Early in the development of the acidizing industry it was recognized that one of the most important problems to be solved in the chemical treatment of any well was the determination of what part of the exposed section in the well should be treated and the selection of the technique that would insure treatment of the desired section.

One of the first techniques adopted for assisting in proper placement of the acid, which is still widely used, is the method of confining the acid to the producing section by means of a column of oil, which is known as the Carr[1] method of treatment, named for its inventor. In the Carr method it is not possible to selectively acidize a specific horizon in a multiple pay zone, so many improvements and modifications of the basic Carr technique were devised to accomplish this result.

In order to overcome the possibility of the acid entering an undesirable section at the bottom of the well, organic gel plugs[2] were introduced into the bottom of the well, which served to halt the entrance of the treating solution into these zones.[3] These chemical gels later liquefied because of bacterial action and were removed from the well with the produced fluid.

In fields where a gas cap existed, as in the Goldsmith field of Ector County, Texas, it was imperative that a treating technique be evolved that would confine the acid to the oil-producing zone below the gas cap. By so doing the oil-productive capacity of the wells could be improved without greatly increasing the gas production and this would lower the gas-oil ratio of the well. The technique employed[4] to achieve this effect utilized two pumps, one for pumping the chemicals down the tubing, the other to simultaneously force oil down the annular space to confine the acid to the oil pay, thus preventing the chemicals from entering the upper gas-bearing zones.

Experience has indicated that gas wells and certain types of oil wells respond better to "stage treating." This technique utilizes the introduction of a certain volume of acid and then allows the well to "clean up" before introduction of the next and usually successively larger stages. Where such methods are employed steps must be taken to keep a disproportionate share of the acid from entering the most permeable and previously treated zones.[5] A special tool

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* Dowell Incorporated, Tulsa, Oklahoma.

[1] References are at the end of the paper.

called the "jet gun" is often used. This device is attached to the bottom of the tubing through which the acid is introduced. It contains many small jets, which cause high-velocity streams of acid to be impinged upon the sections of lower permeabilities.

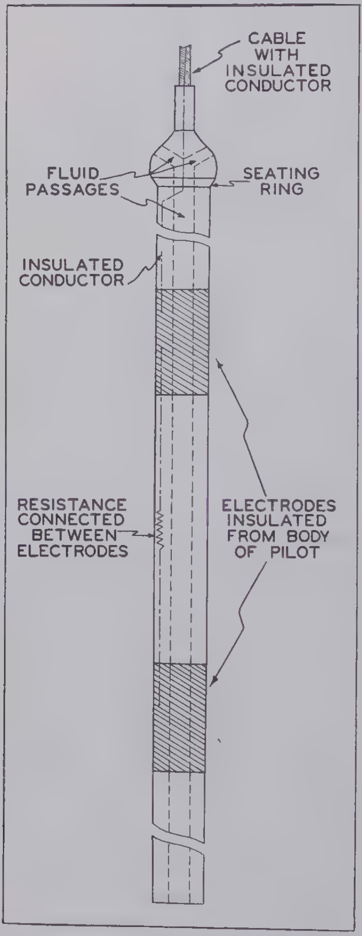
CABLE WITH INSULATED CONDUCTOR
FLUID PASSAGES
SEATING RING
INSULATED CONDUCTOR
RESISTANCE CONNECTED BETWEEN ELECTRODES
ELECTRODES INSULATED FROM BODY OF PILOT

Fig. 1.—Construction of electrode unit.

All of these selective acidizing methods depend for their success upon the completeness and accuracy of well data provided by the geologist and engineer representing the well owner. Often it has been learned, too late in many instances, that the zones to be treated were inaccurately located or the data were so meager that no definite conclusions could be reached in regard to the location of the permeable, porous zones that contained the oil.

The Interface Locator

Recently there has been placed in field service an apparatus known to the trade as the Electric Pilot, which can be used (1) to determine the relative permeability of various zones in a well bore and (2) to introduce the treating chemicals into the desired zones. Relative permeability is determined by measuring the fluid-injection rate into all parts of the exposed formation, and acidizing control is effected by introducing acid and oil into various parts of the formation at such rates that the top or bottom level of the acid in the borehole, as indicated by the electric pilot, is held at the desired level.

Briefly, the instrument is an electrical fluid-interface locator, the electrical circuit of which is completed when the electrodes in the well are in contact with a conductive fluid, such as acid or salt water, but is not completed when immersed in a nonconductive fluid such as oil. The electrode unit is run into the well on an insulated single-conductor cable, the insulated copper core and the external steel wires forming the two conductors required for the electric circuit from the surface to the bottom of the well.

A diagrammatic sketch of the electrode unit is given in Fig. 1. Essentially, the instrument consists of a steel tube several feet long, on the outside of which are mounted two electrodes, completely insulated from the steel tube. The insulated conductor wire of the cable is connected to the upper electrode, and the lower electrode is electrically connected to the upper by means of an insulated wire having a resistance of several hundred ohms. In order to complete the electric circuit in the well, it is necessary to establish electric connection between the body of the pilot and one or both of the electrodes.

In some applications the interface locator is run inside the tubing and in others it is run in the casing and open hole with no tubing in the well. The seating ring shown near the top of the electrode in Fig. 1 is required only when it is run inside the tubing. The seating ring seats in a companion piece previously installed on the bottom of the tubing, thus causing any fluid introduced into the tubing to go into the fluid passages of the electrode unit and out the bottom of the unit.

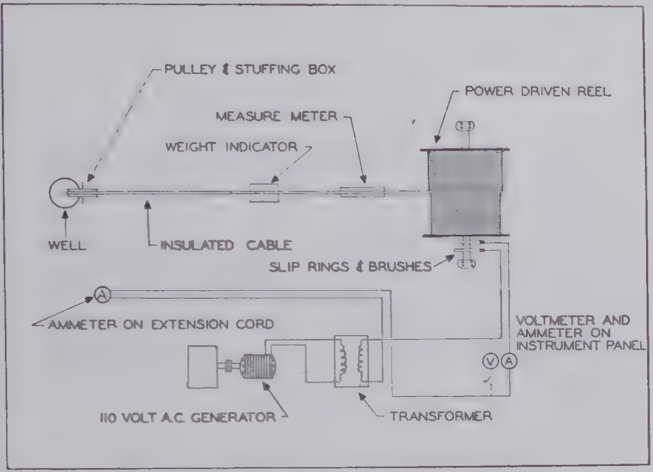

FIG. 2.—SCHEMATIC DIAGRAM OF EQUIPMENT.

The surface equipment used with the interface locating unit is shown in Fig. 2. This consists of a power-driven reel for spooling the insulated cable, with a measure meter and weight indicator installed on the line near the reel. The insulated copper conductors in the cable and the cable sheath are connected to slip rings, mounted at one end of the reel. This permits electrical readings to be taken while the cable is in motion. Operating current for the unit is supplied by a small alternating-current generator connected to a transformer. An ammeter in the circuit shows the amount of current flowing, and this is a direct indication of the location of the conductive fluid with respect to the electrodes at the bottom of the well. On the commercial units for this service, all the equipment is mounted in a light panel truck.

Actual operation of the interface locator is most easily understood by reference to Fig. 3, in which the electrodes are shown completely immersed in oil, immersed half in acid and half in oil, and completely immersed in acid. The illustrations show the electrode unit connected with a battery (*B*) and an ammeter (*A*), and also the ammeter readings that can be expected under each of the three conditions possible at the bottom of the hole during use.

In the left-hand illustration of Fig. 3, only oil is in contact with the electrodes, and as oil is a nonconductor the electric circuit between the electrodes and the body of the pilot is not completed. No current flows in the circuit and the ammeter registers zero.

In the center illustration, acid is in contact with the lower half of the steel body of the electrode unit, and oil is in contact with the upper electrode and the upper part of the steel body. Acid is a conductor of electricity, therefore the electric circuit is completed between the lower electrode and the body of the unit. Current now flows in the circuit from the battery to the top electrode, through the resistance, to the bottom electrode, through the acid to the body of the unit, to the ammeter and back to the battery. A definite amount of current is now flowing in the circuit and the ammeter will show about a half scale deflection.

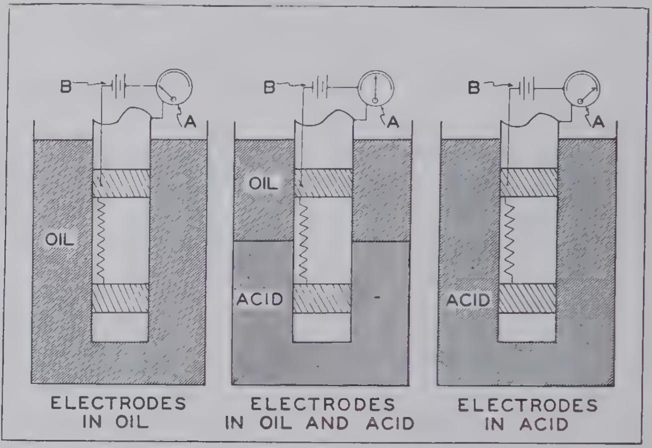

FIG. 3.—OPERATION OF INTERFACE LOCATOR.
No current flows when electrode unit is immersed in oil but a definite current flows when one or both electrodes are in acid.

In the right-hand drawing of Fig. 3, only acid is in contact with the electrode unit. In this case the electric circuit is completed between the lower and the upper electrodes and the body of the unit. The current now flows in the circuit from the battery to the top electrode, through the acid to the body of the unit, to the ammeter and back to the battery. As the resistance between the two electrodes has now been shorted out, considerably more current will flow than was possible in the previous illustration. The ammeter will now indicate practically a full-scale deflection.

Although these illustrations have assumed acid and oil to be the two fluids in contact with the electrodes, other conductive and nonconductive fluids will work equally well. In making permeability surveys it is customary to use salt water instead of acid.

The illustrations in Fig. 3 are analogous to the actual happenings in a well. The operator observes an electrical instrument, and when this instrument reads zero it means that the acid or salt water is below the bottom electrode. When the instrument gives a half-scale deflection it means that the interface between acid or salt water and oil is between the bottom and top electrodes. When the instrument gives a full-scale deflection it means that the conductive fluid is at or above the top electrode.

Location of the interface between a conductive and a nonconductive fluid in a well makes possible two distinct types of well applications: (1) control of fluid-injection rates so as to maintain the interface at the desired level, and (2) surveying wells by following the movement of the interface under controlled conditions. Under the first classification the most important commercially to date has been selective acidizing of the lower pay in a zone containing two or more pays, although successful acidizing of an upper pay has also been accomplished using an electrode having an electrical connection practically the reverse of that described previously. The most important commercial application of the moving electrode technique is the determination of the relative permeability of a formation by observing the rate of the oil-water interface while fluid is being injected into the formation.

Acidizing of Selected Zone

The electric interface locator has proved of great value in the acidizing of many wells with high gas-oil ratios, high water-oil ratios, two or more pay zones, sands exposed above or below limestone, leaky casing, or wells that have been deepened. In such wells it is desirable that acid be placed in a selected zone in order to produce best results.

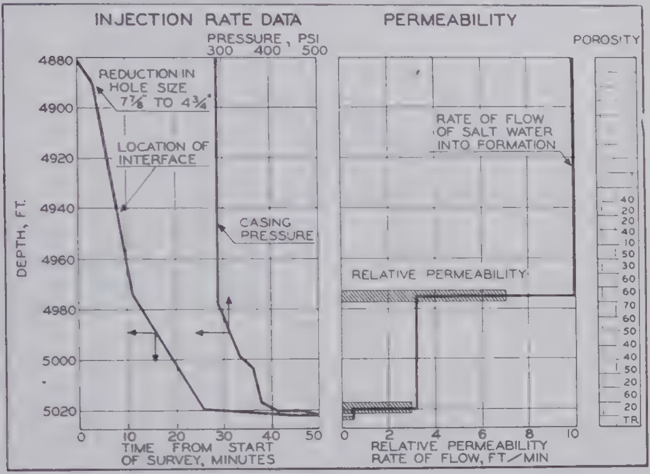

Fig. 4.—Permeability before acidizing.

Before acidizing, the formation had two permeable zones with a relative permeability of nearly seven in the upper zone and three in the lower zone.

To acidize the lower pay of a multiple-zone well the electrode seating nipple is installed on the lower end of the tubing and sufficient tubing is run in the well to place the electrode seat 2 ft. above the top level to which acid should rise during the treatment. The electrode unit is then run into the tubing and seated in the bottom of the tubing. As the electrode seating ring is near the top end of the unit, this permits the two electrodes to project out below the bottom of the open-end tubing, with the mid-point between the electrodes at the top acid level.

During the treatment, acid is pumped down the tubing and discharged into the well below the electrodes, and simultaneously, oil is pumped into the annulus between the tubing and casing. By this means an acid-oil interface is obtained that is relatively free from turbulence and from the possibility of emulsion formation. The relative pumping rates of acid and oil employed during the treatment are then determined by the readings on the electric meter at the surface. When the meter gives a full-scale deflection, indicating that the acid level is too high, either the acid-introduction rate is slowed down or the oil rate speeded up. If the acid level is too low, as indicated by a zero reading on the instrument, the acid introduction rate is speeded up or the oil slowed down.

It is generally found that the ratio of oil to acid required to hold the top of the acid at the desired point is much less toward the end of the acid treatment than at the beginning. This is exactly what would be expected, as it means that the permeability of the lower zone is increased by the acid while the permeability of the upper zone, which received no acid, remains substantially unchanged. Fig. 5 shows the injection rates for acid and oil used in treatment of a well in the West Texas area where the electric interface locator was used to confine the acid to the bottom pay in a well having two pay zones. At the start of this treatment the acid-injection rate was approximately half the oil-injection rate, while at the end of the treatment, acid and oil were being pumped at substantially the same rate.

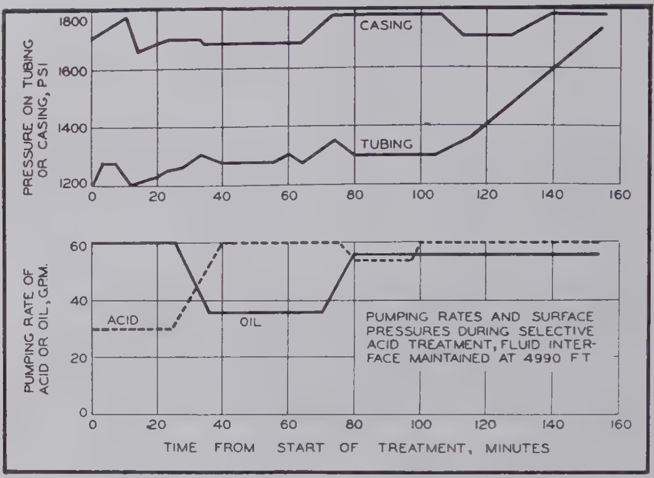

Fig. 5.—Acid-treatment data.

During treatment of the lower pay, the casing pressure remained nearly constant, but the rate of introduction of acid increased as the treatment progressed.

Without some means of continuously determining the location of the top of the acid throughout the treatment, selective acidizing by pumping acid down the tubing and oil down the annulus is merely guesswork. The electric interface locator makes this method of selective acidizing an accurate and reliable procedure.

General well data and results obtained from a number of selective acidizing treatments in which the electric interface locator was used are shown in Table 1. This gives an idea of some of the various types of wells and different techniques to which the electric interface locator has been found applicable.

Determination of Relative Permeability

Various techniques have been used for permeability surveys, but the one that seems to give the best results in a majority of wells consists of the introduction of sufficient salt water into the bottom of the well to cover completely all of the section to be surveyed and the forcing of this salt water into the formation by introduction of oil into the well. The rate of fall of the salt water-oil interface is determined, by means of the interface locator, during the injection of salt water into the formation. From these data the relative permeability of various sections of the formation can be calculated.

A good example of the technique employed and the data obtained is given for a well in the Slaughter pool of Hockley County, West Texas, on which a permeability survey was made before and after a selective acidizing treatment. This well had an original total depth of 5028 ft. with 5½-in. casing set at 4720 ft. On completion of the well in 1939, it was given a 5000-gal. acid treatment but no attempt was made to direct the acid to any particular zone. Production history of the well over a 3-yr. period indicated that selective re-acidizing of the less permeable zones should result in increased production.

In making the permeability survey before re-acidizing, sufficient salt water was introduced into the bottom of the well to fill approximately to the casing point. The well was then filled with oil, and oil was pumped into the well at a rate of 10 gal. per min. throughout the survey. The pressure at the surface is shown on the curve marked "Casing Pressure" on Fig. 4. This shows that the pressure was constant at 295 lb. until after the interface passed the first permeable zone, and that after this the pressure rose rather rapidly. The location of the salt water-oil interface was followed with the electric interface locator, and a graph of interface location against time was made from these data (Fig. 4).

TABLE 1.—*Data on Selective Acidizing*

Well Location	Pay Formation	Oil Production, Bbl. per Day		Thickness of Pay, Ft.	Part of Pay Treated	Acid Used, Gal.	Remarks
		Before	After				
Pawnee County, Kansas.	Arbuckle	96	960	13	Lower 3 ft.	1,000	Gas-oil ratio reduced from 31 to 2 M cu. ft. per bbl.
Creek County, Oklahoma	Arbuckle	6	30	8	8 ft.	1,000	Arbuckle and Bartlesville open, acid held to Arbuckle
Rogers County, Oklahoma.	Mississippi	2	4	40	Lower 20 ft.	1,000	Interface locator used to prevent circulating casing seat
Pawnee County, Kansas.	Arbuckle	100	1,128	13	Lower 6 ft.	1,500	Treated in new hole following deepening operation
Russell County, Kansas.	Kansas City	960	4,200	58	Lower 35 ft.	4,000	Deepened to new pay. Acid held to bottom pay
Greenwood County, Kansas.	Kansas City	1	4	17	Lower 8 ft.	1,000	Acid kept out of water pay above oil
Butler County, Kansas.	Mississippi	8	83	30	Lower 13 ft.	1,000	Acid held to lower pay, which received no acid on previous treatment
Seminole County, Oklahoma.	Viola and Simpson	30	60	99	Upper 17 ft.	1,500	Reverse electrode used to direct into Viola above Simpson
Crane County, Texas.	Ellenburger	No test	8,000	23	Lower 20 ft.	5,000	Acid confined to pay below gas cap. Gas-oil ratio after treatment, 600
Ector County, Texas.	Permian	50	152	120	Lower 95 ft.	1,000	Lower section of pay acidized to prevent increase in gas

For comparison with this injection permeability data, a "relative porosity" log, derived from microscopic determinations run on well cuttings, is also shown in Fig. 4. There seems to be some general agreement between the two sets of data but in this case it might have been difficult to pick the permeable sections from the well-cutting data.

The survey showed that the upper permeable zone at 4975 ft. had twice the permeability of the lower zone at 5020 ft., so the lower zone was acidized with 5000 gal. of acid, using the interface locator to control the injection of acid. The electrode unit was seated in the lower end of the tubing and so located that the acid would be held below 4990 ft. Oil was pumped down the casing and acid down the tubing in the quantities required to maintain the interface at the desired point. Fig. 5 shows the pumping rates for oil and acid; also the casing and tubing pressures used throughout the treatment.

After acidizing, the well was put on production until practically all the spent acid had been produced from the formation. An after-treatment permeability survey was then conducted, using a technique similar to that used on the pretreatment survey. However, it was found that this survey could be conducted with the hydrostatic head of a well full of oil, so no surface pressure was put on the well except near the end of the survey. This lower pressure on the formation caused the injection rates into all zones to be proportionately less than on the first survey.

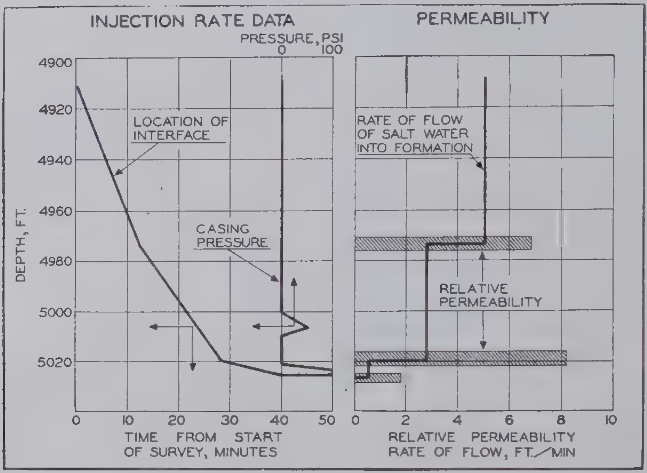

Fig. 6.—Permeability after acidizing.
The formation exhibits the same permeable zones as before acidizing but the permeability of the lower zone has been increased by a factor of three.

The data obtained on the after-treatment permeability survey are shown in Fig. 6, and a compilation of the results of both surveys is given in Table 2.

Table 2.—*Results of Permeability Survey*

Time	Injection Rates, Ft. per Min.			Flow Rates into Permeable Zone, Ft. per Min.			Relative Permeability		
	Above 4975	Between 4975-5020	Below 5020	4925	5020	5023-26	4975	5020	5023-26
Before acidizing......	10.05	3.09	0.16	6.96	2.93	0.16	6.96	2.93	0.16
After acidizing.......	4.96	2.90	0.50	2.06	2.40	0.50	6.96	8.11	1.69

The injection-rate data given in Table 2 are calculated from the slopes of the curves in Figs. 4 and 6, which represent the quantity of fluid entering all permeable zones below the interface. These data are given in feet per minute, which is nearly equivalent to gallons per minute, since a hole drilled with a 4¾-in. bit holds approximately 1 gal. per foot. The flow rate into a given zone is obtained by taking the difference in the injection rates above and below the permeable zone.

The relative permeabilities before acidizing, as shown in Table 2, are numerically the same as the flow rates into the respective zones. In calculating the relative permeabilities after acidizing it was assumed that the section at 4975 ft. had the same permeability before and after the acidizing treatment, since no acid entered this section. Using 6.96 to represent the permeability of the section at 4975 ft., the relative permeability of the section at 5020 ft. after acidizing will be 8.11, and the section at 5026 will be 1.69. Thus, the permeability of the zones at 5020 and below were approximately 3.2 times as great after acidizing as before.

The electric interface locator or "Electric Pilot" has been used in numerous types of wells in several states. The results obtained to date indicate that by the use of this instrument new economies in well treating may be secured through resultant improvement in acidizing techniques. Improved acidizing techniques, or the introduction of the chemicals into the proper zones in a well, should result in better wells and increased recoveries.

The use of this apparatus in surveying wells for the location and relative permeabilities of porous sections in all kinds of wells, including those used in secondary-recovery projects, will provide data of much value in determining completion and workover practices.

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2. J. J. Grebe and S. M. Stoesser: U. S. Patent 1998756 (1934).
3. P. E. Fitzgerald and F. R. Holland: Use of Gel Compounds Aids in Acidizing Wells. *Oil and Gas Jnl.* (Feb. 4, 1937) 46.
4. R. J. Sullivan: Gas-Oil Ratio Control in Flowing Wells. Amer. Petr. Inst. Drill. and Prod. Practice (1937) 103.
5. G. L. Leach: Improved Gas Well Acidizing. *The Oil Weekly* (March 24, 1941) 17.

DISCUSSION

G. H. Fancher,* Austin, Texas.—The apparatus described by Hefley and Fitzgerald should be very useful in petroleum engineering work. Not only can practical results be achieved, but also valuable data result, which can be applied by the engineers to the solution of problems of specific interest. Many applications of the apparatus, in addition to those described by the authors, will occur to the petroleum engineer in the field.

The only fly in the ointment, so to speak, is the misuse of the term "relative permeability." Relative permeability has been defined,[6] standardized and agreed upon for use in the industry as the ratio of the effective permeability of a sand or rock to single fluid phase to the permeability of the sand or rock. The "relative permeability" of Hefley and Fitzgerald in no sense conforms to this definition. No doubt the objective in using the term was simplification, but simplification at the price of confusion is unwarranted. It is suggested that the use of the word "relative" as an adjective modifying permeability be avoided, except where the sense of A.P.I. code 27 is indicated.

It is further suggested that the type of permeability data with which this paper is concerned be discussed in terms of permeability ratios, the specific ratios being defined only as necessary. The term "average permeability" is in good standing to represent the weighted average of a permeability profile, and the fluid intake ratio of sand or sections of a sand is directly in proportion to the average permeability.

L. E. Elkins,* Tulsa, Okla.—It is believed that the development of the electric pilot and the applications reviewed in this paper are in reality preliminary to the development and perfection of technique that ultimately will result in exact scientific control of various types of remedial work. It seems as though the ultimate goal to be reached from the standpoint of determining complete well information includes a record of the diameter of the well bore, an accurate permeability profile, and a qualitative determination of the nature of fluids entering the well bore at any one specific interval. With this information available, reconditioning becomes a matter of applied mechanics.

P. E. Fitzgerald (author's reply).—The term "relative permeability" as used in our paper refers to the relative permeability of one permeable zone to another permeable zone in the same well. We have discussed our use of this term with several engineers, and find that there is no misunderstanding of our meaning.

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* Professor of Petroleum Engineering, University of Texas.

[6] Standard Procedure for Determining Permeability of Porous Media. Amer. Petr. Inst. Code No. 27, Ed. 2 (April 1942).

* Assistant Chief Production Engineer, Stanolind Oil and Gas Company.

Vapor-liquid Equilibria of Natural Gas-Crude Oil Systems

By M. B. Standing* and D. L. Katz,† Member A.I.M.E.

(Los Angeles Meeting, October 1942)

Abstract

Equilibrium data are reported on the composition and densities of coexisting vapor and liquid phases as a function of pressure and temperature for four hydrocarbon systems prepared from crude oil and natural gas. The data were observed over a range of pressures from 1000 to 8220 lb. per sq. in. and at temperatures ranging from 35° to 250°F.

The compositions of the hydrocarbon systems were such that the critical temperatures of the mixtures were lower than the range of the investigation. Under these conditions, it is shown that the composition of the systems has a marked effect upon both the absolute value of the equilibrium constants and the change of the constants with pressure for the several components comprising the system. From weight-balance considerations, it has been possible to construct the partial phase diagram of a mixture of a 49.9° A.P.I. crude oil and natural gas having a gas-oil ratio of 3660 cu. ft. per barrel. Descriptions of the apparatus used, the analytical procedure, the material used, and the equilibrium measurements are included.

A knowledge of the physical behavior of naturally occurring hydrocarbon mixtures is fundamental to the treatment of many problems in the production, transportation and refining of petroleum. The recent discoveries of pools having formation pressures up to 7500 lb. per sq. in. and higher, and the development of full-scale equipment to operate at pressures of 5000 lb. per sq. in. or more have greatly increased the need for knowledge of the composition, temperature, pressure and density relationships of coexisting vapor and liquid hydrocarbon phases.

The following paper presents the results of investigations upon 22 mixtures of natural gas and crude oil of known composition that had been brought to equilibrium under controlled conditions of temperature and pressure. Data are presented upon the densities and compositions of the coexisting vapor and liquid phases for four different systems containing hydrocarbon material having boiling points from minus 258°F. to well over 1000°F. The data were observed over a pressure range from 1000 lb. per sq. in. to 8220 lb. per sq. in. and a temperature range from 35° to 250°F.

The accepted method of computing the physical relationship between two coexisting phases of a hydrocarbon mixture is by use of the "equilibrium constant" K as proposed by Souders, Selheimer, and Brown.[11] By definition,

$$K = y/x \qquad [1]$$

where

y = mol fraction of the component in the vapor phase,

x = mol fraction of the component in the liquid phase,

K = equilibrium constant of the component at the equilibrium temperature and pressure.

Abstract of a thesis submitted by M. B. Standing to the Horace H. Rackham School of Graduate Study, University of Michigan.

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* Standard Oil Company of California, La Habra, California.

† Professor of Chemical Engineering, University of Michigan, Ann Arbor, Michigan.

[11] References are at the end of the paper.

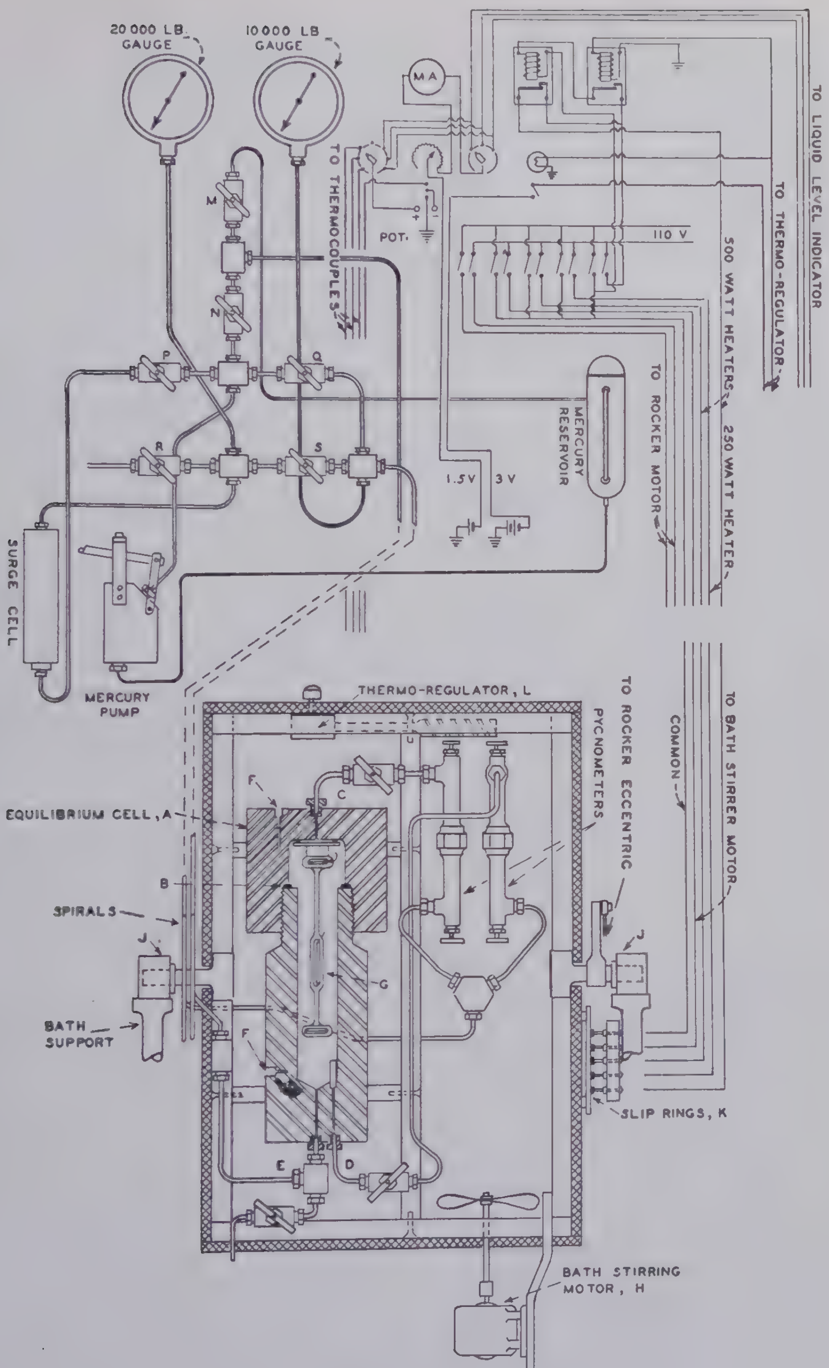

FIG. 1.—DIAGRAM OF APPARATUS.

The use of the equilibrium constant in the computation of vapor-liquid equilibria has been explained.[3–5]

Equilibrium constants determined from hydrocarbon systems composed of two or three components have received considerable study.[1,2,8,10]

Katz and Hachmuth[6] have reported the results of investigation on a crude oil-natural gas system that covered a range of temperatures from 40° to 200°F. at pressures up to 3422 lb. per sq. in. More recently, Webber[14] has published data on a hydrocarbon gas-absorber oil system up to 5014 lb. per sq. in. Since the completion of the experimental program reported by this paper, equilibrium constants for a volatile hydrocarbon "distillate" system have been reported.[9]

While the use of the equilibrium constant enables one to compute the vapor-liquid equilibrium, it is also of considerable importance to be able to evaluate the properties of the individual phases. Previous papers[12,13] prepared from the results of this investigation have presented methods for computing the densities of the coexisting vapor and liquid phases at pressures up to 10,000 lb. per sq. in. and temperatures to 250°F.

Equilibrium Apparatus

In order to study the effect of pressure, temperature, and system composition upon the vapor-liquid equilibria and the properties of the coexisting phases at pressures between 1000 and 10,000 lb. per sq. in., the apparatus shown diagrammatically in Fig. 1 was constructed.

The equilibrium cell *A*, of approximately 750 ml. capacity, was constructed from a solid piece of steel. A satisfactory seal between the base and the cap was obtained by use of a soft copper gasket *B*, deformed by a tongue-and-groove joint. Fluid lines to the cell consisted of a vapor sample line *C*, a liquid sample line *D*, and a fluid-injection line *E*. Two thermocouple wells *F* were drilled into the cell wall, which permitted the recording of the temperature ½ in. from the inner wall. In addition, three high-pressure electrical leads (not shown) were brought in through the cell cap to service the liquid-level indicator *G*.

The cell was supported in a steel framework, which also served as a support for the ½-in. thick asbestos walls of the constant-temperature bath and for the bath stirring motor *H*. The framework in turn was supported by two spindles and bearings *J*, which permitted the rotation of the bath and contents about a horizontal axis.

The constant-temperature bath was heated by use of a 500-watt and a 250-watt heater manually controlled. A second 500-watt heater was automatically controlled through suitable relays by a bimetallic thermoregulator *L*. Air was used as the heating medium and could be maintained within ±0.3°F. Below room temperatures, a small finned cooling coil placed within the bath and supplied with iced brine permitted operation down to 30°F. A high-speed stirrer gave rapid circulation of the air within the bath.

The entire bath and contents could be oscillated through angles of plus and minus 30° from the horizontal by an arrangement of a motor, gear reducer, and eccentric arms attached to one of the spindles. The rate of oscillation was approximately eleven cycles per minute.

Electrical connections to the heaters and to the bath-stirrer motor were through an arrangement of five slip rings, *K*. No slip rings were provided for the thermocouple circuits or for the 1½ and 3-volt circuits, but sufficient wire length was allowed for the oscillation of the bath.

Two steel pycnometers of approximately 25 ml. capacity were used in taking samples of the phases within the cell. These were connected to the cell through suitable valves and could be detached from the cell and removed from the air bath through a small hand hole in the wall of the thermostat.

At all times connection between the pressure gauges on the control panel and the base of the equilibrium cell was maintained by means of a 10-ft. length of pressure tubing coiled in the form of a spiral and placed around one of the spindles. A second spiral, as shown in Fig. 1, connected the pycnometers to the control panel.

A mercury piston displacement pump and a surge cell of approximately 325 ml. capacity were connected to the pressure manifolds on the control panel. An arrangement of valves on the pressure manifolds permitted the addition of mercury or hydrocarbon material to the equilibrium cell at any time.

MATERIALS

The materials used throughout the investigation consisted of a dry natural gas, a 14.2-lb. Reid vapor-pressure natural gasoline, and a 32.2° A.P.I. stock-tank oil from the Schuler pool, Arkansas. The natural gasoline was blended with the stock-tank oil in varying proportions and the resulting mixtures, identified as "crudes" in the following paper, were brought to equilibrium with various amounts of natural gas.

The compositions of the three materials are listed in Table 1. Owing to a preliminary treatment in the field with activated carbon, the natural gas was essentially free of material heavier than propane. Two lots of natural gasoline were used, both having only a trace of isobutane and lighter material present. Lot 1 was used throughout the series A, B, D, and E runs and lot 2 was used in all other investigations. The stock-tank oil was the same as that used by Katz and Singleterry[7] in an investigation of the critical phenomena.

Twenty-two equilibrium mixtures were studied. According to the isotherm investigated and the properties of the mixtures, the 22 runs have been segregated into eight series, as identified in Table 2.

TABLE 1.—*Analyses of Materials Used*

NATURAL GAS

Component	Mol Fraction
Nitrogen	0.0043
Carbon dioxide	0.0051
Methane	0.9320
Ethane	0.0425
Propane and heavier	0.0161
	1.0000

NATURAL GASOLINE

Component	Mol Fraction	
	Lot 1	Lot 2
Normal butane	0.0813	0.1134
Isopentane	0.1285	0.1353
Normal pentane	0.2695	0.2478
Isohexanes	0.0712	0.1169
Normal hexane	0.2095	0.1274
Heptanes and heavier	0.2400	0.2622
	1.0000	1.0000
Molecular weight of heptanes and heavier	107.4	106.8

SCHULER (ARKANSAS) STOCK-TANK OIL

Cut No.	Boiling Range, Deg. F.	Specific Gravity 60/60	Molecular Weight	Volume, Per Cent
1	86–252	0.7035	94	12.5
2	252–377	0.7753	127	12.5
3	377–506	0.8173	176	12.5
4	506–615	0.8506	225	12.5
5	615–720	0.8865	277	12.5
6	720–800	0.9232	375	12.5
7	800+	0.995	730	25.0

TABLE 2.—*Properties of the Equilibrium Series*

Series	Isotherm, Deg. F.	Natural Gasoline in Crude, Volume Per Cent	Crude Gravity, Deg. A.P.I.	Average Gas-crude Ratio, Cu. Ft. per Bbl.
A	120	50	49.9	7,088
B	250	50	49.9	7,480
C	120	50	49.9	3,575
D	120	75	62.0	7,280
E	120	25	40.9	7,270
F	250	50	49.9	3,680
G	35	50	49.9	3,700
H	49	50	49.9	3,675

Average gas-crude ratio of series A, B, D and E, 7180.

Average gas-crude ratio of series C, F, G and H, 3660.

From the analyses presented in Table 1 and the data of Table 2 the eight series of runs may be further divided according to composition. Table 3 presents the computed compositions of the four systems investigated.

TABLE 3.—*Composition of Systems Investigated*

Component	Mol Fraction			
	49.9° A.P.I. Crude, 7180 Cu. Ft. per Bbl.	49.9° A.P.I. Crude, 3660 Cu. Ft. per Bbl.	62.0° A.P.I. Crude, 7180 Cu. Ft. per Bbl.	40.9° A.P.I. Crude, 7180 Cu. Ft. per Bbl.
Nitrogen	0.0038	0.0035	0.0037	0.0039
Carbon dioxide	0.0046	0.0042	0.0045	0.0047
Methane	0.8307	0.7551	0.8166	0.8456
Ethane	0.0381	0.0346	0.0375	0.0389
Propane	0.0163	0.0148	0.0160	0.0166
Butanes	0.0124	0.0162	0.0149	0.0099
Pentanes	0.0287	0.0522	0.0407	0.0162
Hexanes	0.0220	0.0396	0.0293	0.0140
Heptanes and heavier	0.0434	0.0798	0.0368	0.0502
	1.0000	1.0000	1.0000	1.0000
Heptanes and heavier:				
Molecular weight	199	199	161	228
Specific gravity	$0.850\,{}^{60}/_{60}$	$0.850\,{}^{60}/_{60}$	$0.807\,{}^{60}/_{60}$	$0.865\,{}^{60}/_{60}$

TABLE 4.—*Densities of Equilibrium Phases*

Run No.	Equilibrium Conditions		Vapor Phase			Liquid Phase		
	Pressure, Lb. per Sq. In. Abs.	Temperature, Deg. F.	Weight of Material from Pycnometer, Grams	Mercury with Sample, Grams	Density, Grams per C.C.	Weight of Material from Pycnometer, Grams	Mercury with Sample, Grams	Density, Grams per C.C.
A-5	1,000	120	4.20[a]	0.10[a]	0.056	194.00	185.9	0.726
A-4 and 41	1,600	120	2.34	None	0.097	17.68	0.25	0.702
A-1	3,185	120	5.45	None	0.224	18.05	0.80	0.696
A-2 and 21	5,270	120	8.30	0.05	0.340	19.15	0.68	0.745
A-3	8,220	120	9.85	0.05	0.404	21.90	1.81	0.814
B-3	1,680	250	2.20	None	0.091	Sample lost		
B-1	2,915	250	3.75	None	0.154	17.58	0.27	0.697
B-2	6,200	250	Samples lost					
C-2 and 21	1,010	120	1.35	None	0.056	18.08	0.29	0.711
C-1	2,880	120	4.93	None	0.203	16.37	0.18	0.652
C-3 and 31	5,330	120	10.13	0.34	0.400	18.58	0.97	0.712
F-1	3,185	250	4.67	None	0.192	16.43	0.20	0.654
F-2	4,315	250	6.73	None	0.277	16.84	0.54	0.657
F-3	5,530	250	8.47	None	0.349	17.10	0.27	0.677
G-1	2,030	35	4.31	0.03	0.176	18.46	2.02	0.665
G-2	3,485	35	9.30	None	0.383	17.17	0.32	0.679
G-3	4,970	35	11.21	None	0.463	20.57	1.64	0.766
H-4	1,815	49	3.53	0.13	0.140	18.53	1.66	0.682
H-2	3,055	49	7.73	0.53	0.296	16.67	0.30	0.659
H-3	5,150	50	12.10	0.62	0.474	19.04	0.37	0.752
D-1	4,330	120	8.05	0.10	0.327	24.85	7.08	0.731
E-1	4,195	120	6.55	0.21	0.261	19.35	0.72	0.753

[a] Weights for three pycnometers of gas.

EXPERIMENTAL TECHNIQUE

The experimental technique employed in obtaining the densities and compositions of the coexisting vapors and liquids for the several systems investigated was as follows. In essence, the method was: (1) to prepare the system by the addition of predetermined amounts of crude and natural gas to the equilibrium cell; (2) to obtain equilibrium between the vapor and liquid phases that were formed and withdraw a sample of each phase; and (3) to fractionate each sample into the individual components down to

TABLE 5.—*Phase-equilibrium Determinations*

Component	A-5 1000 Lb. per Sq. In. Abs., 120°F.			A-4 and 41 1600 Lb. per Sq. In. Abs., 120°F.			A-1 3185 Lb. per Sq. In. Abs., 120°F.			A-2 and 21 5270 Lb. per Sq. In. Abs., 120°F.		
	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$
	Vapor	Liquid		Vapor	Liquid		Vapor	Liquid		Vapor	Liquid	
Methane	0.9194	0.2225	4.12	0.9159	0.2965	3.09	0.8855	0.4385	2.02	0.8588	0.5558	1.54
Ethane	0.0354	0.0364	0.97	0.0340	0.0472	0.72	0.0370	0.0526	0.703	0.0355	0.0369	0.97
Propane	0.0122	0.0223	0.547	0.0106	0.0273	0.388	0.0120	0.0251	0.479	0.0159	0.0197	0.81
Butanes	0.0082	0.0182	0.450	0.0073	0.0380	0.192	0.0042	0.0130	0.323	0.0086	0.0151	0.570
Pentanes	0.0092	0.7006		0.0129	0.1382	0.093	0.0171	0.0709	0.242	0.0262	0.0502	0.522
Hexanes	0.0066			0.0069	0.1060	0.065	0.0139	0.0813	0.171	0.0150	0.0463	0.324
Heptanes and Heavier	0.0090			0.0124	0.3468	0.036	0.0303	0.3186	0.095	0.0400	0.2760	0.145

Component	A-3 8220 Lb. per Sq. In. Abs., 120°F.			B-1 2920 Lb. per Sq. In. Abs., 250°F.			D-1 4330 Lb. per Sq. In. Abs., 120°F.			E-1 4195 Lb. per Sq. In. Abs., 120°F.		
	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$
	Vapor	Liquid		Vapor	Liquid		Vapor	Liquid		Vapor	Liquid	
Methane	0.8439	0.6076	1.39	0.8573	0.4158	2.10	0.8340	0.5260	1.58	0.8918	0.5178	1.72
Ethane	0.0386	0.0427	0.90	0.0372	0.0333	1.11	0.0372	0.0357	1.04	0.0367	0.0392	0.94
Propane	0.0151	0.0175	0.865	0.0147	0.0176	0.83	0.0141	0.0181	0.78	0.0146	0.0205	0.712
Butanes	0.0118	0.0142	0.830	0.0110	0.0228	0.483	0.0116	0.0202	0.575	0.0095	0.0190	0.500
Pentanes	0.0261	0.0359	0.728	0.0183	0.0574	0.320	0.0394	0.0650	0.605	0.0110	0.0308	0.357
Hexanes	0.0201	0.0256	0.782	0.0167	0.0657	0.255	0.0262	0.0790	0.332	0.0123	0.0415	0.296
Heptanes and Heavier	0.0444	0.2565	0.173	0.0268	0.3874	0.069	0.0375	0.0256	0.147	0.0241	0.3312	0.073

Component	C-2 and 21 1010 Lb. per Sq. In. Abs., 120°F.			C-1 2880 Lb. per Sq. In. Abs., 120°F.			C-3 and 31 5330 Lb. per Sq. In. Abs., 120°F.			C-2 3485 Lb. per Sq. In. Abs., 35°F.		
	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$
	Vapor	Liquid		Vapor	Liquid		Vapor	Liquid		Vapor	Liquid	
Methane	0.9340	0.2234	4.18	0.8892	0.4850	1.83	0.7986	0.5641	1.42	0.8221	0.5700	1.44
Ethane	0.0346	0.0313	1.10	0.0356	0.0415	0.86	0.0346	0.0351	0.98	0.0326	0.0339	0.96
Propane	0.0098	0.0188	0.520	0.0103	0.0166	0.620	0.0128	0.0137	0.92	0.0093	0.0117	0.79
Butanes	0.0042	0.0225	0.187	0.0079	0.0222	0.356	0.0212	0.0244	0.86	0.0191	0.0326	0.585
Pentanes	0.0107	0.1540	0.0695	0.0244	0.0884	0.276	0.0448	0.0573	0.78	0.0470	0.0890	0.528
Hexanes	0.0046	0.1300	0.0354	0.0146	0.0871	0.168	0.0307	0.0434	0.70	0.0265	0.0628	0.422
Heptanes and Heavier	0.0021	0.4200	0.005	0.0180	0.2592	0.069	0.0573	0.2620	0.218	0.0434	0.2000	0.217

Component	G-3 4970 Lb. per Sq. In. Abs., 35°F.			F-1 3185 Lb. per Sq. In. Abs., 250°F.			F-2 4310 Lb. per Sq. In. Abs., 250°F.			F-3 5530 Lb. per Sq. In. Abs., 250°F.		
	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$	Composition Mol Fraction		Exp. $K = y/x$
	Vapor	Liquid		Vapor	Liquid		Vapor	Liquid		Vapor	Liquid	
Methane	0.7818	0.5799	1.35	0.8439	0.4470	1.89	0.8054	0.5124	1.57	0.7850	0.5766	1.36
Ethane	0.0364	0.0376	0.96	0.0402	0.0336	1.20	0.0387	0.0395	0.98	0.0432	0.0397	1.09
Propane	0.0126	0.0146	0.86	0.0106	0.0161	0.658	0.0117	0.0146	0.80	0.0131	0.0150	0.87
Butanes	0.0220	0.0274	0.80	0.0172	0.0331	0.520	0.0196	0.0300	0.654	0.0200	0.0260	0.77
Pentanes	0.0502	0.0705	0.71	0.0277	0.0884	0.314	0.0454	0.0790	0.561	0.0486	0.0650	0.75
Hexanes	0.0339	0.0518	0.655	0.0110	0.0318	0.346	0.0271	0.0655	0.414	0.0313	0.0407	0.77
Heptanes and Heavier	0.0631	0.2182	0.289	0.0494	0.3500	0.141	0.0521	0.2590	0.201	0.0588	0.2370	0.248

heptanes and to determine the properties of the heptanes-and-heavier residue.

Sample Preparation

Initially the cell was pressured with the natural gas and the quantity computed from the pressure-temperature-volume relationships of the dry gas. A volume of liquid crude necessary to yield the desired gas-crude ratio was then forced into the equilibrium cell by displacing it from the surge cell with mercury. By watching the action of the pressure gauges, the point at which mercury entered the spiral leading to the equilibrium cell could be determined. Owing to the formation of an emulsion between mercury and the crude oil while agitating, an effort was made to keep at a minimum the mercury entering the equilibrium cell in the process of preparing the sample.

TABLE 6.—*Molecular Weights and Specific Gravities of Heptanes-and-heavier Fractions*

Run No.	Vapor Phase		Liquid Phase	
	Mol. Wt.	Spec. Gr. 60/60	Mol. Wt.	Spec. Gr. 60/60
A-5	110[a]	0.742[a]	162[b]	
A-4 and 41	110[a]	0.742[a]	196	0.850
A-1	127	0.775	240	0.863
A-2 and 21	131	0.788	279	0.904
A-3	144	0.802	356	0.954
B-1	115[a]	0.753[a]	231	0.870
C-2 and 21	100[a]	0.725[a]	186	0.836
C-1	113	0.750	186	0.844
C-3 and 31	151	0.800	240	0.881
F-1	130	0.768	216	0.862
F-2	139	0.791	256	0.888
F-3	157	0.808	290	0.912
G-2	128	0.765	215	0.863
G-3	145	0.792	315	0.903
D-1	123	0.788	268	0.893
E-1	130	0.771	242	0.877

[a] Estimated.

[b] Molecular weight for pentanes plus.

Before the equilibrium cell was filled with the natural gas, the two pycnometers were filled with mercury and placed in position within the constant-temperature bath. The lines for sampling vapor and liquid, between the pycnometers and the equilibrium cell, were then filled with mercury by pumping a small amount through each pycnometer in turn.

Obtaining Equilibrium and Sampling

With the required natural gas and crude in the cell, the cell was oscillated at constant temperature for a sufficient length of time to ensure equilibrium. It is of interest to note that if the crude oil was introduced into the bottom of the cell in as quiescent a manner as possible and the oscillations started, the decrease in the cell pressure due to the mutual solution of the gas and crude oil was as high as 1000 lb. per sq. in. for the first oscillation, but after about six oscillations no further decrease in pressure could be detected on the pressure gauge. This was good evidence that equilibrium was obtained very rapidly and that continued oscillations for 45 min. at constant temperature gave the required equilibrium between the two phases in the cell.

TABLE 7.—*Computed Liquid Volumes*

Run No.	Pressure, Lb. per Sq. In. Abs.	Temperature, Deg. F.	Material in Cell, Grams	Density Liquid, Grams per C.C.	Density Vapor, Grams per C.C.	Volume Per Cent Liquid
A-5	1,000	120	66.7	0.726	0.0564	3.0
A-41	1,600	120	113.9	0.702	0.097	9.3
A-1	3,185	120	220.7	0.696	0.224	15.6
A-2	5,270	120	315.3	0.745	0.340	21.0
A-3	8,220	120	357.3	0.814	0.404	19.1
B-1	2,915	250	149.3	0.697	0.154	8.7
C-2	1,010	120	94.9	0.716	0.056	11.2
C-1	2,880	120	261.4	0.652	0.203	33.0
C-31	5,330	120	354.2	0.712	0.400	25.0
F-1	3,185	250	219.5	0.654	0.192	22.6
F-2	4,315	250	270.1	0.657	0.277	22.8
F-3	5,530	250	297.3	0.677	0.349	19.0
G-1	2,030	35	254.6	0.665	0.176	34.2
G-2	3,485	35	347.5	0.679	0.383	29.0
G-3	4,970	35	372.8	0.766	0.463	13.3[a]
H-2	1,815	49	218.5	0.682	0.140	28.5
H-3	3,055	49	330.3	0.659	0.296	41.0
H-4	5,150	49	369.5	0.752	0.473	8.9
D-1	4,330	120	249.7	0.731	0.327	2.4
E-1	4,195	120	259.0	0.753	0.261	18.0

[a] Evidence of third phase separation.

At the conclusion of the oscillatory period, the equilibrium cell was allowed to remain in a vertical position for 15 min., to allow the phases to separate.

Samples of the equilibrium liquid and vapor phases were in turn transferred to the

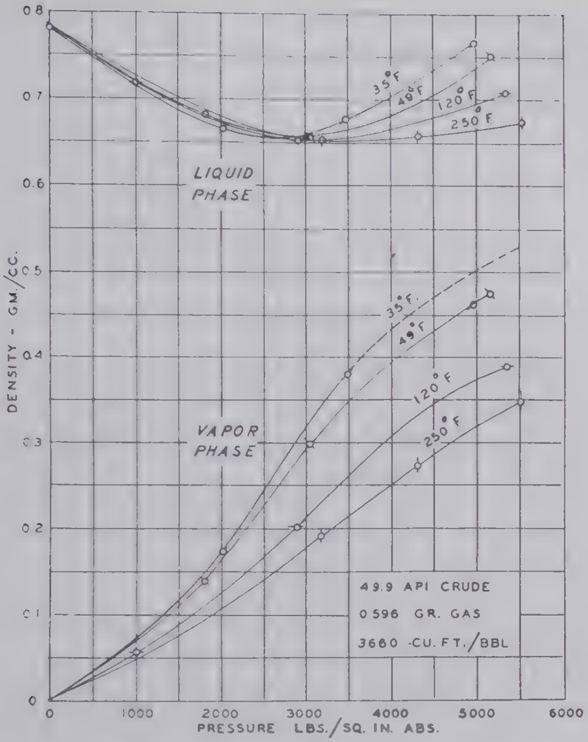

FIG. 2.—VARIATION OF PHASE DENSITIES WITH PRESSURE.

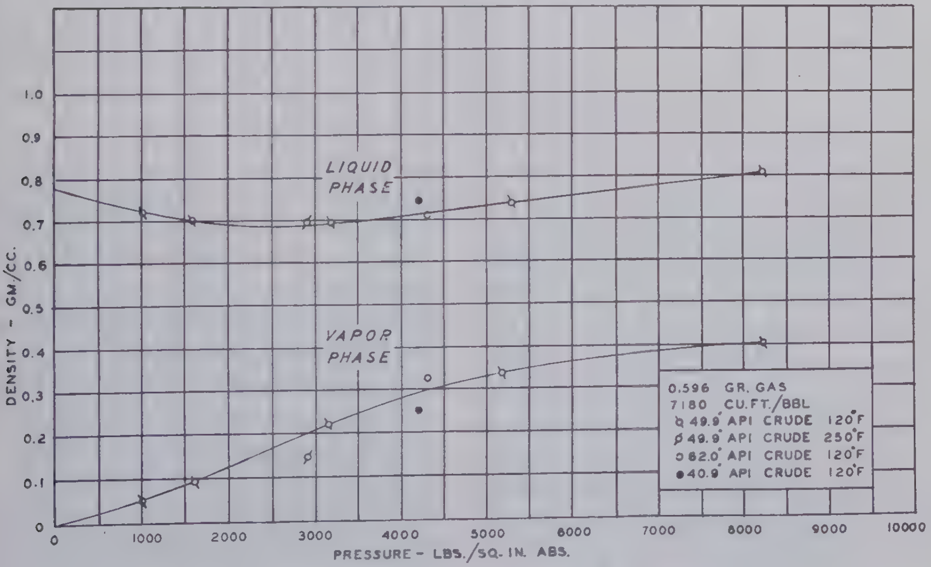

FIG. 3.—VARIATION OF PHASE DENSITIES WITH PRESSURE.

pycnometers at constant pressure by mercury displacement. The pycnometers were then sealed, removed from the constant-temperature bath and weighed.

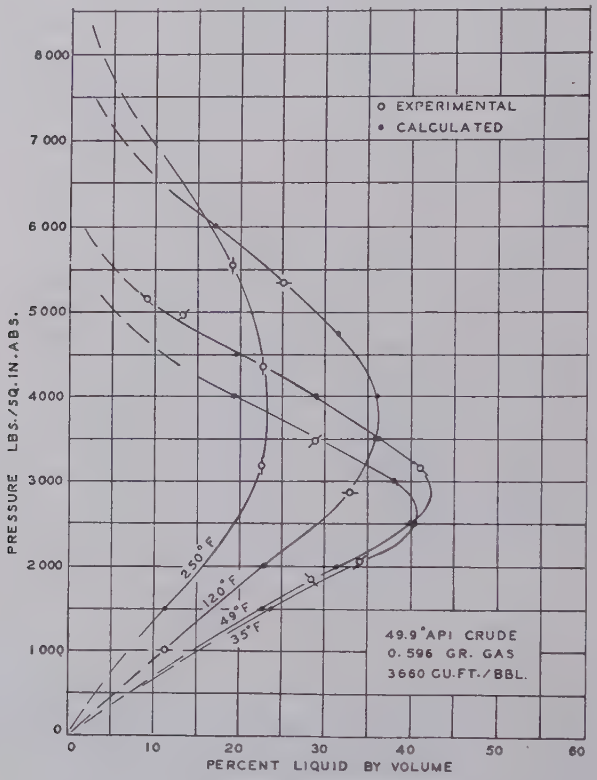

FIG. 4.—VARIATION OF LIQUID VOLUME WITH CELL PRESSURE.

Fractional Analyses of Samples

The fractionating of the equilibrium vapor and liquid samples into their separate components was carried out in a two-column apparatus. The contents of the pycnometers were discharged into a small topping column, from which the components lighter than heptane could be distilled into a low-temperature column for fractionation into the individual components. The residue from the topping column and any material boiling above hexanes remaining in the low-temperature column were combined as "heptanes and heavier."

The density of the heptanes-and-heavier fraction was determined by the use of small glass pycnometers and the value obtained corrected to 60°F. The molecular weight was determined by the cryoscopic method, using water-saturated benzene as the solvent.

Before any sample was removed from the steel pycnometers, they were again weighed, and the weight was checked with that obtained immediately after they were removed from the constant-temperature bath. In only one instance was a difference greater than 0.05 grams apparent, and that sample was discarded. By weighing the pycnometers after the fluids had been discharged into the fractionating columns, the densities of the equilibrium phases could be determined. This procedure also afforded a check on the fractionation results.

RESULTS

Of the 22 equilibrium mixtures prepared, 16 were completely investigated as previously outlined; four mixtures were investigated only for the phase-density relationships, while the remaining mixtures were lost before complete data could be obtained.

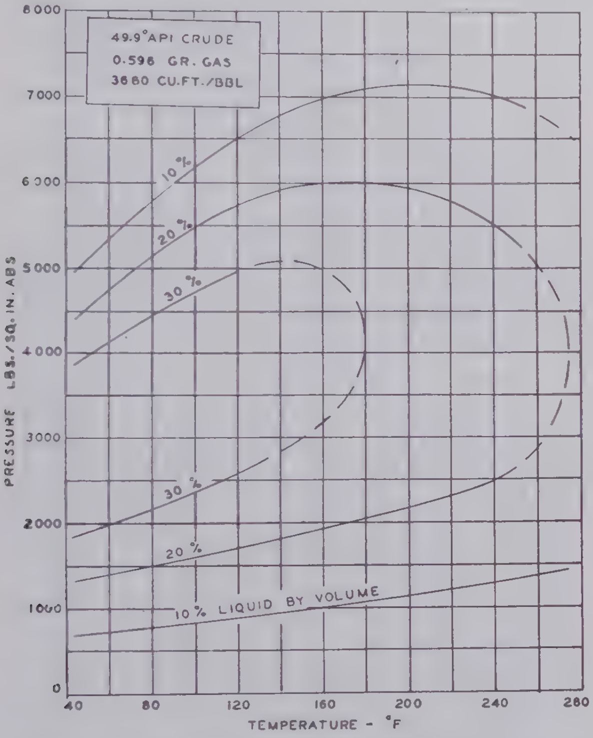

FIG. 5.—PARTIAL PHASE DIAGRAM OF MIXTURE OF NATURAL GAS AND CRUDE OIL.

The densities of the equilibrium liquid and vapor phases as determined from the pycnometer weighings are presented in Table 4. These data are shown graphically in Figs. 2 and 3.

Table 5 gives the composition of the two phases and the computed equilibrium constant K.

In Table 6 are tabulated the molecular weights and specific gravities of the heptanes-and-heavier fractions. Where the amount of sample was insufficient to determine these properties experimentally, estimated values are shown.

In addition to the densities of the coexisting phases, the total weight and volume of the hydrocarbon material composing the system were known at each equilibrium condition. The volume of the liquid phase, therefore, could be computed by means of the following weight balance:

$$d_L V_L + d_G V_G = W \qquad [2]$$

where

d_L, d_G are densities of the liquid and gas phases respectively,

V_L, V_G are the volumes of the liquid and gas phases, respectively,

W is the weight of material in the cell.

If V_s is the volume occupied by the system, Eq. 2 may be solved for V_L as follows:

$$d_L V_L + d_G (V_S - V_L) = W \qquad [3]$$

or

$$V_L = \frac{W - d_G V_S}{d_L - d_G} \qquad [4]$$

temperatures studied were above the critical temperature of that particular system. Needless to say, mixtures having higher gas-oil ratios at the same temperatures would be even further removed from their critical temperature.

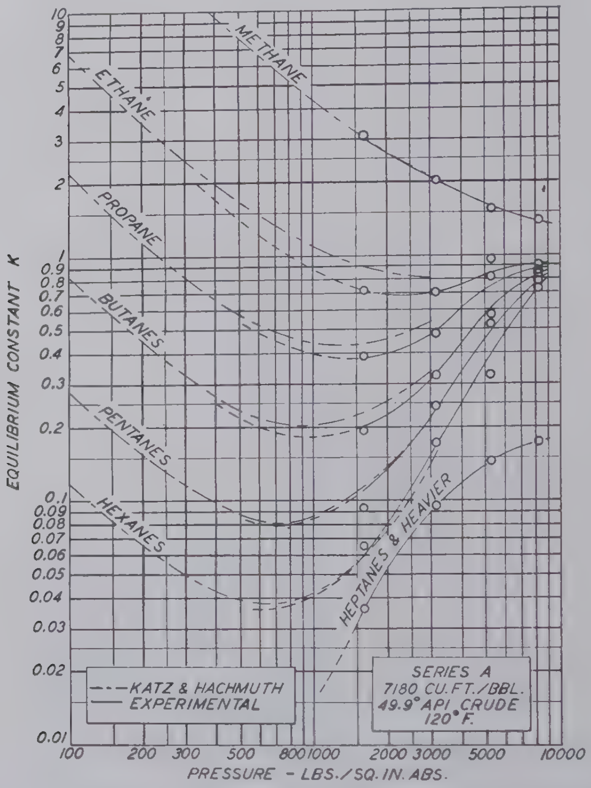

Fig. 6.—Variation of equilibrium constants with pressure.

Table 7 presents the computed liquid-phase volumes of the experimental equilibrium runs.

Fig. 4 shows the variation of the volume of the liquid phase with pressure for the system prepared from the 49.9° A.P.I. crude and natural gas in the ratio of 3660 cu. ft. per bbl. In addition to the calculated percentage of liquids listed in Table 7, points have been calculated from the smoothed curves of Fig. 2 and smoothed curves of W vs. pressure. Since all of the isotherms exhibit a point of maximum percentage of liquid, it is evident that the

Since the crude oil used in these experiments contained material having very high boiling points and molecular weights, it was impossible to cause complete transfer of the material in the liquid phase to the vapor phase by the mechanism of increasing the pressure on the system. For this reason the location of the dew-point line involves considerable uncertainty and the usual procedure of extrapolating the isotherms of percentage of liquid vs. pressure of Fig. 4 to zero per cent liquid could result in large errors.

A partial phase diagram for the system 3660 cu. ft. per bbl., obtained by cross-plotting the curves of Fig. 4, is presented in Fig. 5. From the behavior of the quality lines, the critical temperature of the system is believed to be considerably less than 0°F.

The composition of the coexisting vapor and liquid phases and the computed equilibrium constants have been presented in Table 5. As a first method of smoothing the equilibrium-constant data, the logarithm of the equilibrium constant was plotted against the atmospheric boiling point of the component. A smooth curve was then drawn to best represent the data of each run. From these smoothed curves, values were used to construct isothermal plots of log K vs. log pressure for the systems investigated.

Fig. 6 shows the variation of the equilibrium constant K with pressure for the crude system 7180 cu. ft. per bbl. and 49.9° A.P.I., while Figs. 7 and 8 present similar data for the 3660 cu. ft. per bbl. system. The data of Katz and Hachmuth have been plotted on these curves for comparison.

A comparison of Figs. 6 and 7 shows that at pressures above 1000 lb. per sq. in. the effect of the composition of the system upon the equilibrium constant-pressure relationships becomes very important. The equilibrium constants of ethane, propane, and butanes in the system 7180 cu. ft. per bbl. are less than those of the determinations for Oklahoma City crude,[6] which in turn

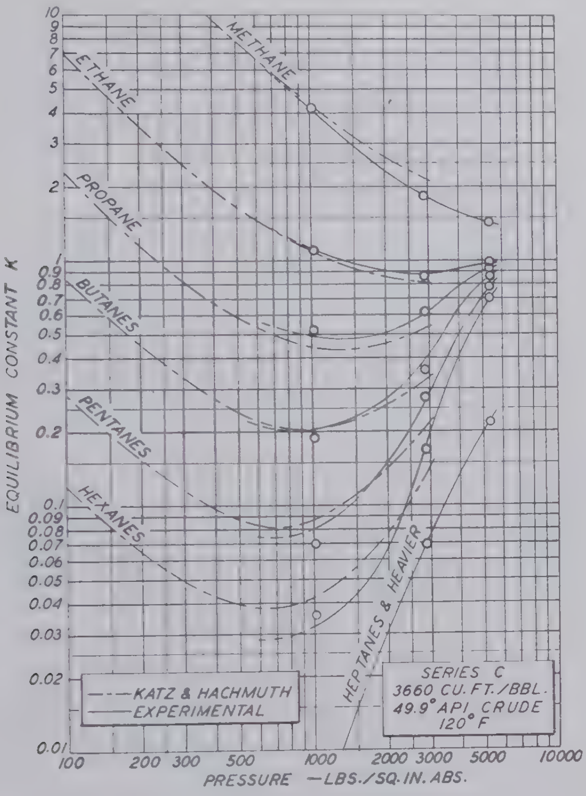

FIG. 7.—VARIATION OF EQUILIBRIUM CONSTANTS WITH PRESSURE.

are less than the constants in the 3660 cu. ft. per bbl. system. At the higher pressures the constants of the components other than the heptanes and heavier approached unity

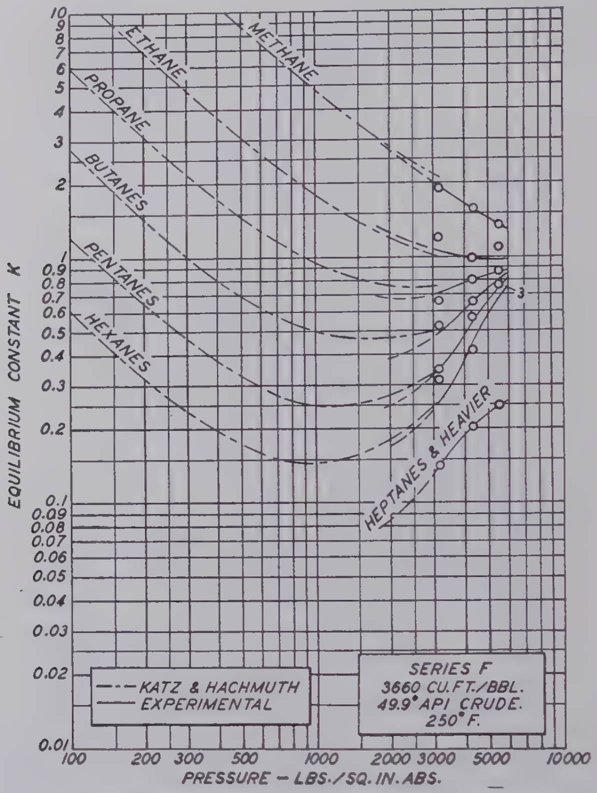

FIG. 8.—VARIATION OF EQUILIBRIUM CONSTANTS WITH PRESSURE.

with a point of inflection at approximately 3000 lb. per sq. inch.

Of special interest and importance to equilibrium calculations in the retrograde region is the behavior of the heptanes-and-heavier constant. This constant is the controlling factor in computing dew-point pressures and in computing the amount of liquid present in a system that is near its dew point. As shown by the curves of Figs. 6, 7 and 8, the equilibrium constant of the heptanes-and-heavier fraction does not necessarily approach unity in the same manner as the other components.

The reason for the particular shape of the heptanes-and-heavier curves is explained by the data of Table 6. An increase of pressure on any particular system caused an increase in the molecular weight and specific gravity of the heptanes-and-heavier fraction in both the vapor and liquid phases. The resultant curve, therefore, represents the equilibrium of a series of heptanes-and-heavier fractions whose volatility decreases with increasing pressure.

SUMMARY

Data upon the composition and densities of coexisting vapor and liquid phases have been obtained for four different systems of natural gas and crude oil of constant composition over a range of pressures from 1000

to 8220 lb. per sq. in. and temperatures from 35° to 250°F. A study of these data shows that:

1. The system of crude oil and natural gas having a gas-oil ratio 3660 cu. ft. per bbl. has a critical temperature less than 35°F.

2. In the retrograde region, the density of the equilibrium liquid phase passes through a minimum value with increasing pressure.

3. The over-all composition of the system has a marked effect upon the values of the equilibrium constants at pressures above 1000 lb. per sq. inch.

4. For the constant-composition systems studied, the equilibrium constants of the components other than methane and heptanes-and-heavier, when plotted against pressure, trend to converge to $K = 1$ at a decreasing rate.

5. In the retrograde region, the behavior of the heptanes-and-heavier equilibrium constant with pressure differs from that of the pure components in the system, because of the decrease in volatility of the heptanes-and-heavier fraction in both the vapor and liquid phases with increase in pressure on the system.

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Viscosity of Natural Gases

By Leo B. Bicher, Jr.* and Donald L. Katz,† Member A.I.M.E.

(New York Meeting, February 1943)

Abstract

A correlation is presented for predicting the viscosities of light paraffin hydrocarbon mixtures such as natural gases for temperatures from 0° to 400°F. and for pressures from atmospheric to 10,000 lb. per sq. in. The correlation is based on the viscosity data for the methane-propane system and requires only a knowledge of the molecular weight of the natural gas. The viscosities of natural gases reported in the literature up to 2500 lb. were reproduced by the correlation with an average deviation of 5.8 per cent.

Introduction

The viscosity of a natural gas is required whenever calculations are made of the pressure drop that occurs while the gas flows through pipes or porous media. Methods of predicting the viscosities of gases at the present operating pressures are not available. This paper presents a simple method of predicting the viscosity of a natural gas in the single-phase region from its molecular weight, temperature, and pressure.

Viscosity of Methane-propane Mixtures

The viscosity of methane, propane, and four of their binary mixtures, 20, 40, 60, and 80 mol per cent, have been determined for pressures from 400 to 5000 lb. per sq. in. and temperatures from 77° to 437°F., with an experimental accuracy of 3.2 per cent.[2] The apparatus used in the investigation was a modification of that employed in previous studies[8,14] on the viscosity of normal paraffin hydrocarbons. It consists of a viscosimeter of the rolling-ball, inclined-tube type,[5,6,7] with auxiliary equipment for making up and charging binary mixtures into the viscosimeter.[2] The viscosity data on the methane-propane mixtures have been plotted as a function of molecular weight with lines of constant pressure, charts of constant temperature in Figs. 1 to 3. These charts are extrapolated at temperatures below 77°F. and at pressures above 5000 lb. per sq. inch.

Prediction of Viscosity from Molecular Weight of a Natural Gas

At atmospheric pressure the viscosity of light hydrocarbon gases increased with increased temperature, contrary to the change of viscosity of liquids with temperature. The atmospheric viscosities of the normal paraffin hydrocarbons have been determined by several investigators[3,4,9,10,12,15,16,17,19] and are plotted in Fig. 4 as a function of molecular weight, with extrapolation to 896°F. and to 220 molecular weight. Data for isopentane and normal pentane show less than 2 per cent difference in viscosity, indicating that Fig. 4 can be used for isomeric paraffin hydrocarbons with an accuracy of approximately 2 per cent. Trautz and Sorg[17] determined the atmospheric viscosities of methane-propane mixtures and showed that they are proportional to the molecular weight. The viscosities of these mixtures

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[2] References are at the end of the paper.

calculated from Fig. 4 represent the experimental data with an average deviation of 0.44 per cent, as tabulated in Table 1, indicating that Fig. 4 can be used for obtaining the atmospheric viscosities of light paraffin hydrocarbon mixtures such as natural gases. Berwald and Johnson[1] determined the atmospheric viscosities of natural gases containing various amounts of nitrogen. Their data are represented by Fig. 4 with an average deviation of about 3.5 per cent, comparable with their experimental accuracy, for gases containing less than 7 per cent of nitrogen. For gases containing higher percentages of nitrogen, a molecular average of the viscosity for nitrogen-free gas as read from Fig. 4 and for pure nitrogen gave satisfactory agreement with the experimental data.

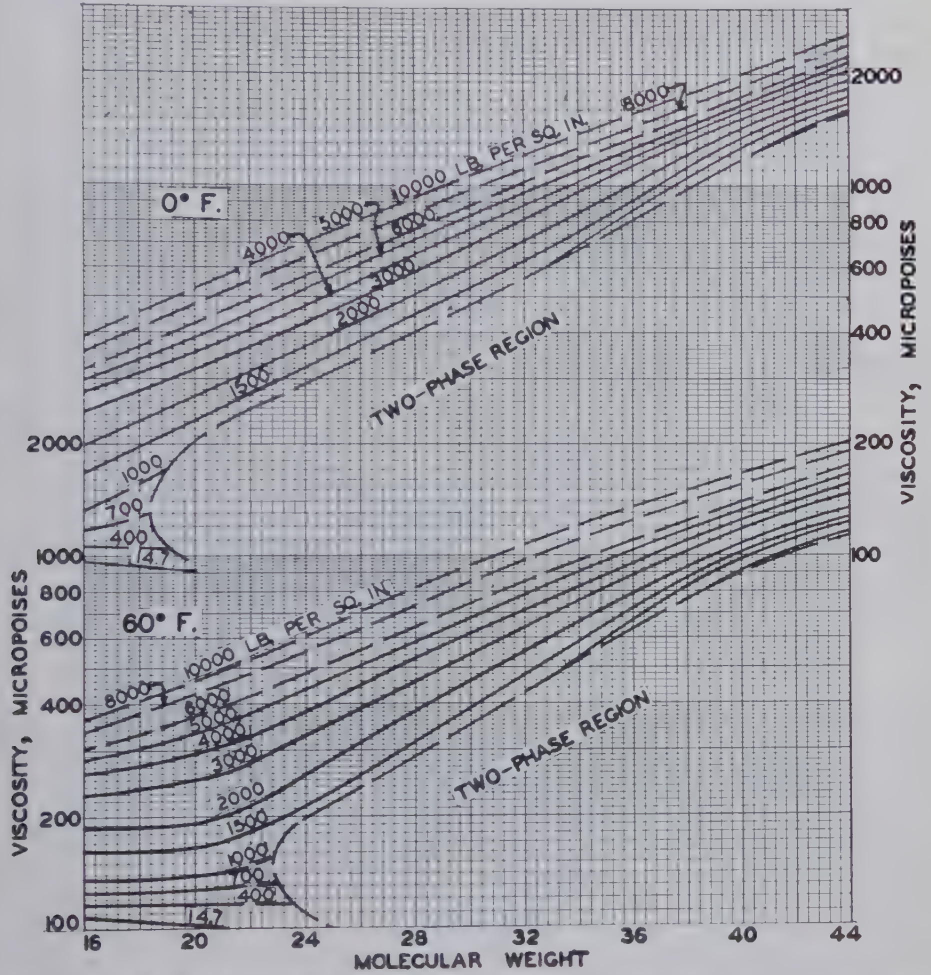

FIG. 1.—CHART FOR PREDICTING VISCOSITIES OF NATURAL GASES FROM DATA FOR METHANE-PROPANE MIXTURES.

Since the viscosity of light paraffin hydrocarbon mixtures is a function of molecular weight at atmospheric pressure, it might be expected that the same relationship would hold for higher pressures. To test the applicability of Figs. 1 to 3 for predicting the viscosities under pressure of light hydrocarbon mixtures such as natural gases from the molecular weights or gravities of the gases, a comparison is made between the predicted viscosities and the experimental values reported for natural gases in Table 1. The predicted viscosities compare with the reported values with an average deviation of 5.8 per cent. This accuracy is comparable with the experimental accuracy of "approximately 5 per cent" reported by Sage and Lacey.[13]

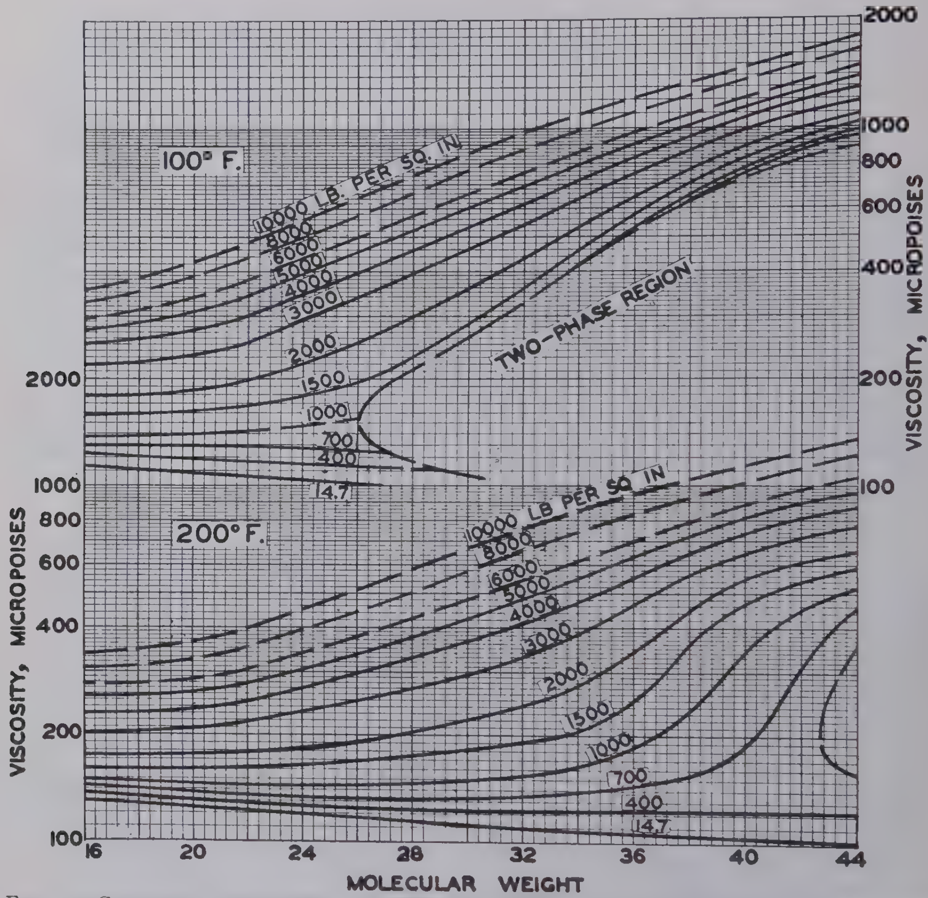

FIG. 2.—CHART FOR PREDICTING VISCOSITIES OF NATURAL GASES FROM DATA FOR METHANE-PROPANE MIXTURES.

The two-phase region indicated in Figs. 1 to 3 is the two-phase region for the methane-propane system. It is known that the two-phase region is a function of the concentration of the constituents in the gas as well as of the molecular weight. For this reason, and because the physical properties of fluids are known to change rapidly near the critical region, Figs. 1 to 3 should not be used for predicting the viscosity of a gas near its critical region, or at a temperature and pressure where two phases exist.

The methane-propane data may be correlated on the basis of molecular weight, pseudocritical temperature, and pseudocritical pressure.[2] The prediction of the viscosity of a natural gas by this relationship requires the analysis of the gas from which the pseudocriticals may be computed. Although this correlation based on pseudocritical temperature and pressure has advantages for predicting viscosities of miscellaneous hydrocarbons, especially in the neighborhood of the two-phase region, it does not reproduce the data on natural gases any more closely than the simple molecular-weight plots.

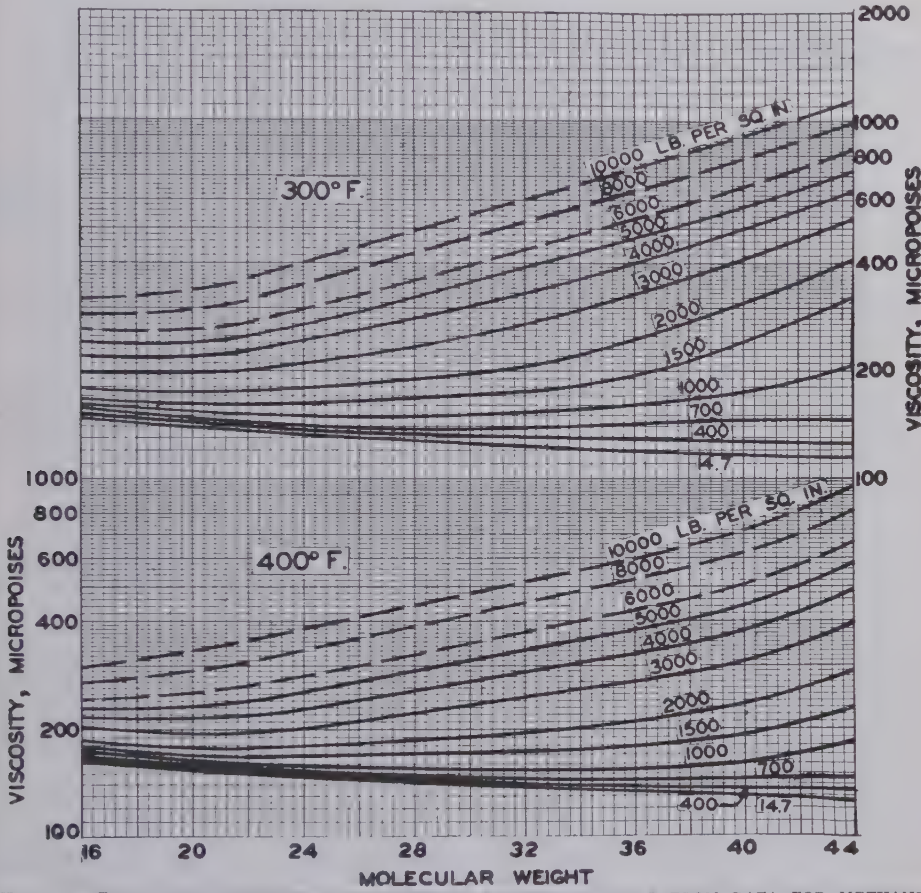

FIG. 3.—CHART FOR PREDICTING VISCOSITIES OF NATURAL GASES FROM DATA FOR METHANE-PROPANE MIXTURES.

EXAMPLE CALCULATION

For purposes of illustration, the viscosity of the lean natural gas reported by Sage and Lacey[13] will be calculated from its molecular weight, at 160°F. and 2500 lb. per sq. in. In this case, the analysis is given but a measured gas gravity (air = 1.0) would have been sufficient.

TABLE 1.—*Comparison of Calculated Viscosities with Reported Values*

Gases Investigated	Mol Per Cent CH_4	Molecular Weight	Temperature, Deg. F	Pressure, Lb. per Sq. In.	Viscosity, Micropoises		Percentage of Error
					Calcd.	Exptl.	
Trautz and Sorg[17] CH_4-C_3H_8 mixture	63.16	26.4	32	14.7	88.3	88.9	−0.68
			104	14.7	100.1	100.8	−0.70
			248	14.7	122.2	123.6	−1.13
			392	14.7	143.5	144.1	−0.42
			464	14.7	153.3	153.2	+0.07
CH_4-C_3H_8 mixture	36.17	33.9	32	14.7	82.0	82.1	−0.12
			104	14.7	93.2	93.4	−0.21
			248	14.7	114.7	115.3	−0.52
			392	14.7	135.2	135.5	−0.22
			464	14.7	144.6	144.3	+0.21
CH_4-C_3H_8 mixture	16.59	39.4	32	14.7	77.8	77.5	+0.39
			104	14.7	88.6	88.4	+0.23
			248	14.7	109.8	109.2	+0.55
			392	14.7	129.8	129.0	+0.62
			464	14.7	139.2	138.5	+0.52
Sage and Lacey[13] Lean natural gas	83.19	20.4	100	500	122	133	− 8.3
				1,500	163	180	− 9.5
				2,500	214	219	− 2.3
			160	500	129	136	− 5.2
				1,500	161	172	− 6.4
				2,500	205	200	+ 2.0
			200	500	133	145	− 8.3
				1,500	160	174	− 8.1
				2,500	192	192	± 0.0
Rich natural gas	69.74	25.0	160	1,000	146	150	− 2.6
				1,500	174	170	+ 2.4
				2,000	203	191	+ 6.3
			200	1,000	144	146	− 1.4
				1,500	166	157	+ 5.7
				2,000	183	169	+ 8.3
Berwald and Johnson[1] Natural gas No. 2	98.4	16.2	60	103.2	108	103	+ 4.9
				304.6	113	103	+ 9.7
				499.8	118	103	+14.6

Calculated average molecular weight = 20.42
Viscosity at 100°F., 2500 lb. per sq. in. = 214 micropoises (from Fig. 2)
Viscosity at 200°F., 2500 lb. per sq. in. = 192 micropoises (from Fig. 2)

Assuming straight-line interpolation between the temperature plots, the viscosity of the lean natural gas at 160°F. and 2500 lb. per sq. in. is

$$214 - \frac{160 - 100}{200 - 100}(214 - 192)$$
$$= 200.8 \text{ micropoises}$$

The corresponding experimental value reported by Sage and Lacey is 200 micropoises.

If the viscosity is changing rapidly with temperature, the viscosities at any given pressure and molecular weight could be plotted as a function of temperature, as a means of interpolation.

TABLE 2.—*The Viscosity of Nitrogen*

Pressure, Lb. per Sq. In. Abs.	Temperature, Deg. F.				
	0	60	100	200	300
	Viscosity, Micropoises				
14.7	156	172	182	206	227
500	163	179	188	213	234
1,000	176	188	196	217	238
2,000	203	208	213	229	247
3,000	234	234	234	242	256
4,000	259	257	257	261	268
6,000	328	315	308	299	295
8,000		373	358	337	323
10,000		433	405	377	351

GASES CONTAINING NITROGEN

Figs. 1, 2 and 3 are based on methane-propane mixtures without the presence of

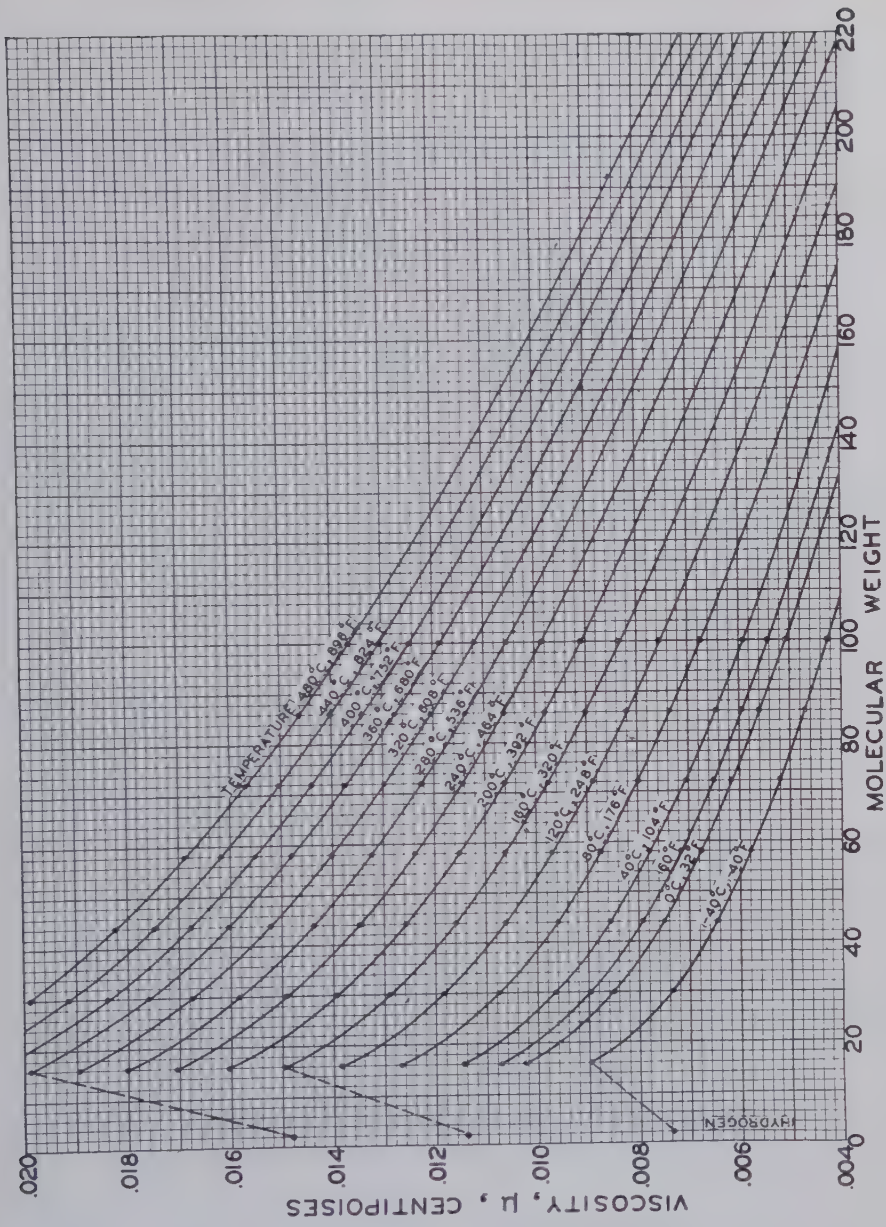

Fig. 4.—Viscosity of paraffinic hydrocarbon gases at atmospheric pressure.

nonparaffin hydrocarbons. Although the relationships presented may apply for unsaturated hydrocarbons, the viscosity of gases containing more than about 5 per cent nitrogen should not be obtained by using Figs. 1 to 3 directly. Since at atmospheric pressure the molal average viscosity of nitrogen and the nitrogen-free hydrocarbon gas reproduces the experimental value, a similar procedure for gases under pressure should be the best approximation now available. Table 2 presents viscosity values for nitrogen interpolated and extrapolated from literature[11,19] data at 25°, 50°, and 75°C. for pressures to 10,000 pounds.

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Selective Adsorption of Hydrocarbon and Water Vapor on Alumina at Atmospheric Pressure

By Chen Chun Ku,* R. L. Huntington† and L. S. Reid,‡ Members A.I.M.E.

(Dallas Meeting, May 1943)

Abstract

The simultaneous adsorption of water and hydrocarbon vapor from natural gas by three grades of alumina has been studied at atmospheric pressure and temperature. Results of this investigation reveal that the presence of water vapor in the gas inhibits the adsorption of hydrocarbon vapor, although the presence of the latter does not have a pronounced effect upon the adsorption of water vapor. Adsorption of water-hydrocarbon mixtures from gas is divided into three phases. In the first, both water and hydrocarbon vapor are adsorbed; in the second, adsorption of water vapor proceeds while desorption of hydrocarbon takes place; in the third phase, the adsorbent approaches complete saturation with respect to both water and hydrocarbon vapors. Both theory and experimental data can be applied to design and operation of commercial dehydration plants, and an illustration is presented.

Introduction

Dehydration of natural gas becomes increasingly important as the operating pressures employed in gas processing and transmission are increased above 500 lb. per sq. in. Gas produced from high-pressure wells is saturated with water vapor when it leaves the reservoir and it continues into the processing plant or transmission system in a saturated condition because of the substantial decrease in temperature due to expansion at the wellhead. Usually this gas is accompanied by liquid water and hydrocarbons that have condensed with the change in temperature and pressure.

Without dehydration, gas temperatures must be held at relatively high levels to prevent solidification of gas hydrates. According to Hammerschmidt's data[8] on the relationship of pressure to the freezing point of natural-gas hydrates, the minimum safe operating temperatures range from 55° to 90°F. for pressures ranging from 500 to 3000 lb. per sq. in., respectively. Often it is difficult to maintain gas temperatures above the hydrate-freezing temperature because of climatic conditions, unless flow-line heaters are installed. Also, in processing gas for its gasoline content at high pressures, it is desirable to employ operating temperatures lower than the hydrate-freezing point. In distributing high-pressure gas, the large pressure drop from line pressure to town-gate pressure often produces sufficient cooling to freeze the regulators and disrupt consumer service. Therefore, it is highly essential to dehydrate high-pressure natural gas if smooth and economical operation is to be maintained at all times.

Few published data are available on the simultaneous adsorption of water and hydrocarbon vapors. The literature contains many mathematical expressions for rate of adsorption in various systems but a rational correlation of the existing rate

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[8] References are at the end of the paper.

data is not possible because of the inherent complexities of the problem. Great complication arises from the variety of mechanisms that may control the rate of adsorption and, because of the complex nature of the adsorption mechanism, no universally acceptable adsorption theory is possible. The various isothermal equations derived by Freundlich,[6] Langmuir,[9] Ubbelohde[13] and Glasstone[7] have been of great value in adsorption studies, but the range of applicability of each of them is considerably limited.

Other references[2–5,11] pertain to the adsorption of water or some other single component from air or gas and do not deal with multicomponent adsorption to any great extent.

COMPARISON OF DEHYDRATION METHODS

Although the water content of saturated gas decreases with an increase in pressure, the criterion of good dehydration is dew-point depression. To lower the dew point from 80° to 30°F., twice as much water would have to be removed from a thousand standard cubic feet of gas processed at 500 lb. per sq. in. as would have to be extracted from a thousand standard cubic feet of the same gas processed at 1000 lb. per sq. in.

One process that has dehydrated gas satisfactorily at these higher pressures employs solid adsorbents and the most successful adsorbents used to date have been various grades of activated alumina. The dew-point depression effected by these materials usually ranges from 80° to 100°F., as compared with an average depression of from 45° to 55°F. obtained with diethylene glycol, and commercial operations at pressures up to 1200 lb. per sq. in. indicate that high pressures have comparatively little effect upon the dehydrating efficiency of the solid adsorbents. However, there are other economic considerations, which, in many instances, favor glycol at lower pressures and have stimulated a search for a more suitable agent for dehydrating liquid for use at higher pressures.

GAS DEHYDRATION AT LOGANSPORT

The research presented here was inspired by observing operations at the dehydration plant owned and operated by the Southern Natural Gas Co. at Logansport, La.[12] This plant was designed to dehydrate one hundred million cubic feet of gas per day at a pressure of 1200 lb. per sq. in. by means of solid adsorbents. It consists of four 3 by 28-ft. towers packed with activated alumina. These towers are operated in parallel, two towers dehydrating the gas while the other pair is being regenerated. Regeneration is accomplished by passing hot gas up through the solid adsorbent at line pressure and temperatures ranging up to 390°F. This hot gas removes the adsorbed water and hydrocarbons, which subsequently are condensed and withdrawn from the system when the hot gas is cooled and scrubbed before it is passed through the active towers for final dehydration. When this plant was placed in operation a rather substantial quantity of hydrocarbon liquid was recovered when the towers were regenerated. Since the amount recovered constituted only a small percentage of the total natural gasoline content of the gas, it was felt that condensate recovery might be made more efficient if more data were obtained on the simultaneous adsorption of water vapor and hydrocarbons. Also, some concern was expressed about the possibility that the dehydrating efficiency of the solid adsorbents might be impaired by the adsorption of these hydrocarbons.

THEORETICAL CONSIDERATIONS

Almost all natural gases contain some water vapor as well as a variable quantity of hydrocarbons, including propane and heavier. Solid adsorbents have a definite adsorptive capacity for any single, pure component but this capacity is influenced by the presence of other components in the gas.

Obviously, water and the heavier hydrocarbons that are present in the gas are different chemically, and it is to be expected that a solid adsorbent would probably exhibit a greater affinity for one than for the other. Then a study of the problem might be further complicated by the possibility that the adsorbent might have a greater affinity for one hydrocarbon than for others. Therefore, the theoretical study of gas dehydration by adsorption consists of three parts:

1. Development of a general adsorption equation with water as the key component.
2. Determination of the ratio of water to hydrocarbons adsorbed at various degrees of saturation of the solid adsorbent.
3. Determination of the distribution of the various adsorbed hydrocarbons with respect to their distribution in the inlet gas.

Practically speaking, the dehydration of natural gas by absorption is truly a batch operation, as indicated above. In such a process unsteady conditions prevail and, since these conditions are not well understood, engineering calculations for such an operation are seriously hampered, and the design of dehydration installations of this type are either empirical or based on pilot-plant tests, or both. If batch equilibrium data were available showing the relationship between the key component in the vapor state and in the adsorbed state, a general adsorption equation could be derived in the following manner:

By material balance around the key component:

$$SX_s + W = SX_\theta \qquad [1]$$

or

$$W = S(X_\theta - X_s) \qquad [2]$$

where

S = total weight of adsorbent in the tower, pounds.

W = weight of key component adsorbed to time θ, pounds.

X_s = pounds of key component adsorbed per pound of adsorbent at the start of the adsorption cycle.

X_θ = pounds of key component adsorbed per pound of adsorbent at time θ.

Since X_θ is nonvariable, it is better to substitute X for X_θ where X may be defined as the pounds of key component adsorbed per pound of adsorbent at any variable time. Then:

$$W = S(X - X_s) \qquad [3]$$

Differentiating Eq. 3 with respect to X:

$$dW/dX = S \qquad [4]$$

or

$$dW = SdX \qquad [5]$$

By definition:

$$dW/d\theta = I - E \qquad [6]$$

where

$dW/d\theta$ = rate of adsorption of the key component, pounds per hour.

I = rate of flow of key component in the inlet gas, pounds per hour.

E = rate of flow of key component in outlet gas, pounds per hour,

or

$$dW = (I - E)d\theta \qquad [7]$$

Equating Eqs. 5 and 7:

$$SdX = (I - E)d\theta \qquad [8]$$

Rearranging:

$$d\theta = \frac{S}{I - E}dX \qquad [9]$$

Integrating: Eq. 9:

$$\int_0^\theta d\theta = \int_{X_s}^{X_\theta} \frac{S}{I - E}dX \qquad [10]$$

or

$$\theta = \int_{X_s}^{X_\theta} \frac{S}{I - E}dX \qquad [11]$$

The relationship between X and $(I - E)$ is determined from the equilibrium curve and then Eq. 11 is integrated graphically. Thus any one of the four variables may be calculated if the remaining three are known. If, for example, it is desired to calculate the time of cycle, this may be done if the rate of flow, concentration of the key component in the inlet and outlet gas, and the initial and final concentration of the key component in the adsorbent are all known.

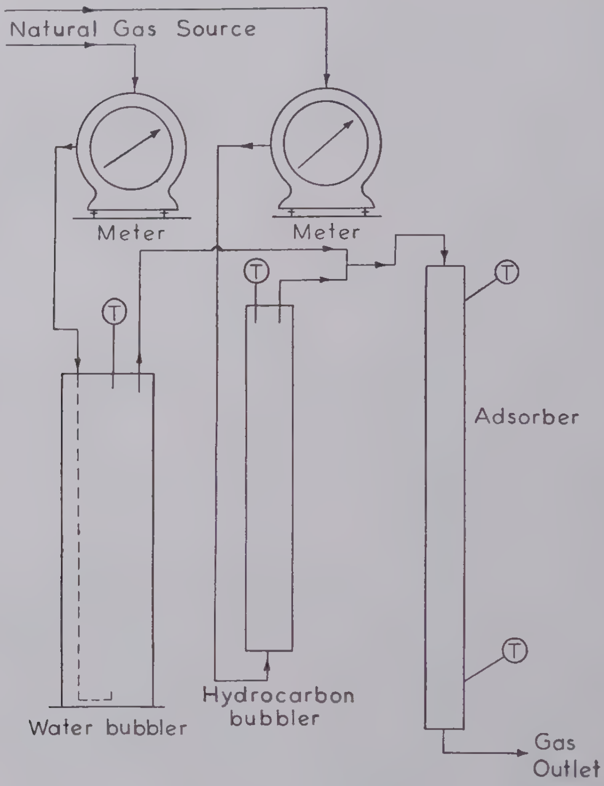

FIG. 1.—FLOW DIAGRAM OF EXPERIMENTAL APPARATUS.

APPARATUS

All experimental work reported here was conducted at, or near, atmospheric pressure, and additional research is being conducted at high pressures at the present time.

A great deal of preliminary investigation was conducted in which pure butane vapor was adsorbed; also butane, hexane, heptane, and water vapors were added, separately, to a stream of natural gas, which was then passed through the adsorbent material. These investigations were preliminary to the work that is reported here in detail.

The apparatus used in this phase of the research is shown in Fig. 1. It was so constructed that water vapor and heavy hydrocarbon vapor could be intimately mixed with natural gas and the composite mixture passed through a chamber containing the adsorbent. The adsorbent chamber was made of 1¼-in. standard pipe, 20 in. long, which was fabricated with two thermometer wells at a distance of 4 in. from each end. This vessel was packed with solid absorbent, which was held in place by tufts of glass wool inserted in each end of the chamber. Natural gas carrying water vapor and vapors of one of the heavier hydrocarbons used was mixed and passed into the top of the adsorber, and the residue gas was removed from the bottom of the chamber. The water vapor was added to the gas by bubbling it through a graduated cylinder filled with water, which saturated the gas with water vapor at the prevailing room temperature. Hydrocarbon vapors were added to another gas stream in precisely the same manner, but the vessel containing the liquid hydrocarbon had a greater volumetric capacity, since all the hydrocarbons employed in this investigation were more volatile than water. Relative quantities of water and hydrocarbons were controlled by varying the rate of gas flow through the two saturators. The two gas streams were measured by means of test meters before saturation, and were then combined and charged into the adsorber.

SOLID ADSORBENTS

Three commercial grades of aluminum oxide were used as the solid adsorbents in this investigation. Florite is the product of the Floridin Company, of Warren, Pa., while Alumina-A and Alumina-H are both products of the Aluminum Ore Company, a subsidiary of the Aluminum Company of America at East St. Louis. The major constituent of all three is hydrated aluminum oxide. Florite contains more iron oxide than the other two, as evidenced by its color, while Alumina-H is impregnated with silica gel. The chemical analysis of Alumina-A is shown in Table 1.

TABLE 1.—*Chemical Analysis of Alumina-A*

COMPONENTS	PER CENT BY WEIGHT
Alumina (Al_2O_3)	92.00
Loss on Ignition (H_2O)	7.00
Soda (Na_2O)	Less than 1.00
Silica (SiO_2)	Less than 0.10
Ferric Oxide (Fe_2O_3)	Less than 0.10
Titania (TiO_2)	Less than 0.10

The physical properties and screen analyses of all three compounds are shown in Table 2.

TABLE 2.—*Physical Properties and Screen Analyses of Solid Adsorbents*

Properties	Florite	Alumina-A	Alumina-H
True specific gravity	3.40	3.30	2.99
Apparent density, lb. per cu. ft.	50	50	54
Specific heat	0.24	0.24	0.23
Average porosity, per cent	34	33	28

Sieve Mesh	Weight Per Cent Retained on Screen		
	Florite	Alumina-A	Alumina-H
4	3.46	5.28	5.55
6	25.40	33.20	34.00
8	57.20	44.43	43.00
10	6.50	8.36	8.40
16	5.05	7.25	7.25
20	0.37	0.25	0.45
Pan	2.02	1.23	1.35
	100.00	100.00	100.00

The average diameters of the solid particles have been calculated from the screen analyses by the method of Fancher and Lewis[10] as 0.109 in. for Florite, 0.0999 in. for Alumina-A, and 0.0998 in. for Alumina-H.

HYDROCARBONS AND WATER

The commercial hexane and heptane were obtained from the Skelly Oil Co. The curves for vapor pressure vs. temperature for these two hydrocarbons have been determined experimentally and are shown in Fig. 2.

The natural gas used in these experiments was taken from the mains of the Oklahoma Natural Gas Co. in Norman, Okla. An analysis furnished by the company is as follows: methane, 93.0 mol per cent; ethane, 5.0; nitrogen, 2.0.

Norman city water was used to supply the vapor for this investigation. While this water is not chemically pure, the saturated vapor-pressure data corresponded with that found in the literature.

Experimental Procedure

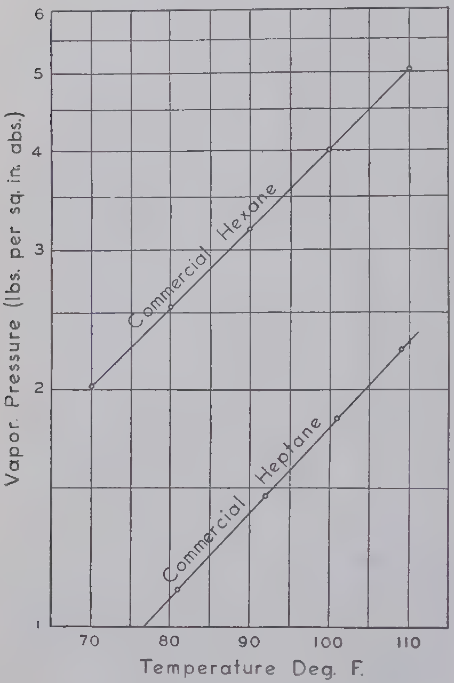

FIG. 2.—VAPOR-PRESSURE DATA FOR COMMERCIAL HEXANE AND HEPTANE.

The fresh dry alumina was weighed and then charged into the adsorber (Fig. 1). Liquid water and hexane or heptane were then charged into separate vessels through which dry gas was bubbled and saturated with water and hydrocarbon vapors. The relative quantities of water and hydrocarbon-saturated gas were calculated before the test was started and the apparatus was closely controlled so that the composition of the gas mixture did not vary during the run. Saturator temperatures and pressures, test meter readings and the adsorber temperatures were observed and recorded at regular intervals.

The quantity of water and hydrocarbon adsorbed in each test was determined by means of a standard charcoal distillation apparatus. The adsorbent was transferred into the flask, 100 ml. of mercury was added and the distillation was carried on until no more liquid was condensed for a period of 15 min. Both the condenser and the receiver jar were well iced to minimize vapor losses during the distillation.

Discussion of Results

Batch adsorption data are very useful, since adsorption as applied to gas dehydration is truly a batch process. For practical purposes it is not necessary to study the distribution of the adsorbed material within the adsorbent body when it is only partially saturated, although this matter is important in theoretical studies of the problem. The batch adsorption data are sufficiently accurate for engineering calculations and, since it is desired to apply these data to Eq. 11, these experimental results are reported on a batch basis.

A series of runs was made in which all three grades of alumina were completely saturated with water and hexane. To obtain data on the effect of variable composition of the inlet gas upon the adsorption capacities of the different materials used, the water-vapor content of the inlet gas was held constant while the hexane-vapor content was varied. The results of this series of tests are shown in Fig. 3. The ratio of hexane to water adsorbed increases directly with the hexane content of the inlet gas and, in the range of 0.1 to 0.7 weight per cent hexane content, Alumina-H shows to advantage over Alumina-A and Florite. However, there is little to choose between the three adsorbents at higher or lower hexane concentrations.

Another series of runs was made on all three adsorbent materials, in which the water and hydrocarbon-vapor concentrations were held constant at 0.00135 lb. of each component per standard cubic foot of gas mixture. These runs were terminated at various stages of saturation and the quantities of water and hydrocarbon adsorbed were determined by mercury distillation. Results of the tests on hexane and water are shown in Fig. 4, while the results of tests employing heptane and water are shown in Fig. 5. Batch equilibrium curves are shown in Figs. 6 and 7 for hexane and water and for heptane and water, respectively.

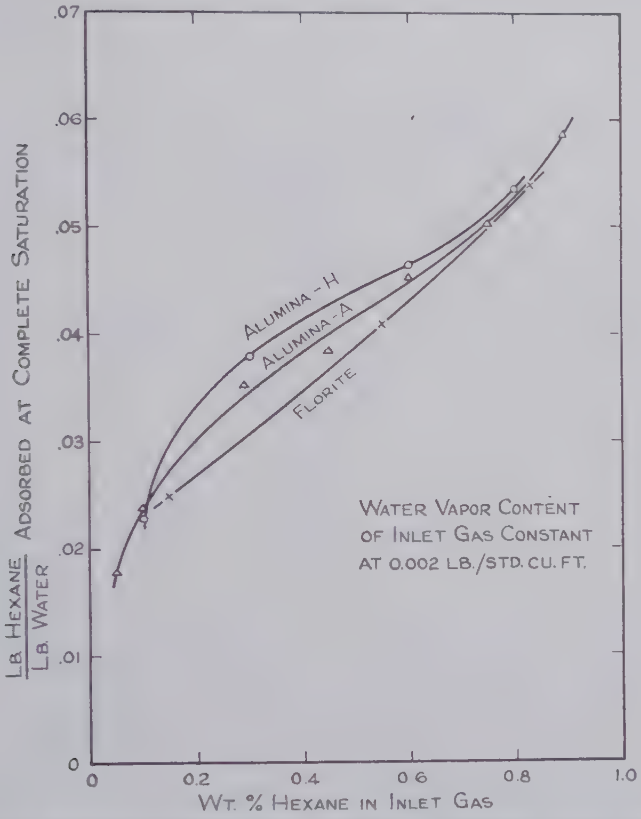

Fig. 3.—Ratio of hexane to water vapor adsorbed at complete saturation vs. hexane content of inlet gas. Water vapor content held constant.

Figs. 4 and 5 indicate that comparable results were obtained using Florite and Alumina-A, but that Alumina-H demonstrated a greater adsorptive capacity for both water and hydrocarbon, probably because of the silica-gel impregnation. These curves also reveal that the adsorption cycle is divided into three distinct phases. In the first phase, both water and hydrocarbon are adsorbed. In the second phase, adsorption of water continues but hydrocarbon that has been adsorbed in the first phase is stripped out; i.e., selective adsorption takes place. In the third phase, the adsorbent is completely saturated with both water and hydrocarbon. In other words, the ratio of hydrocarbon to water adsorbed is constant in the first phase, varies widely in the second, and again becomes constant in the third phase. It should be noted, however, that good commercial operation never permits the third phase to be reached, and that it is an economic impossibility to recover the maximum quantity of hydrocarbon adsorbed in the first phase because of the tremendous solid adsorbent capacity required for a very nominal gas throughput and because of the frequency of regenerating cycles.

Another series of runs was made on Florite alone, in which the proportions of hexane to water were arbitrarily established at 2 to 1, 3 to 1, and 4 to 1. These runs were terminated at various stages of the adsorption cycle and the water and hydrocarbon recoveries were determined by mercury distillation. Results of these tests are shown in Fig. 8. Here it is seen that composition of the inlet gas affects the maximum quantity of hydrocarbon adsorbed. However, hydrocarbon desorption takes place rapidly after the maxima have been reached and, in this range, the effect of composition of the inlet gas on the quantity of hydrocarbon adsorbed is negligible. Also, the data indicate that the hexane-water ratio has little, if any, effect on the adsorption of water.

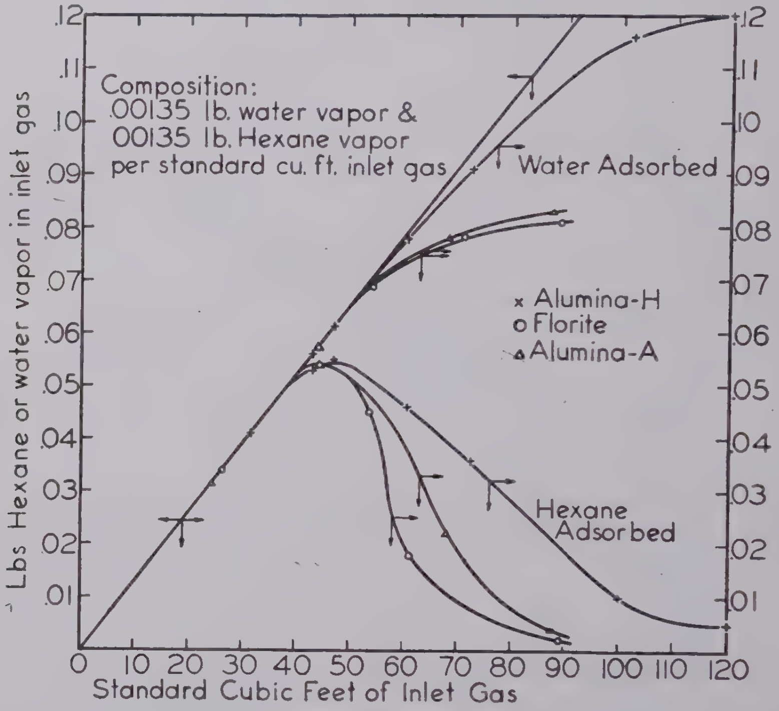

FIG. 4.—ADSORPTION OF HEXANE AND WATER VAPOR ON THREE GRADES OF ALUMINA.

In conducting preliminary experiments, which have not been reported here, it was observed that each of the three solid adsorbents used in this investigation had a definite adsorptive capacity for each of the components studied when they were carried in the gas stream individually. Yet the adsorptive capacity of these solid adsorbents for the individual component was reduced to some extent when other components were present. It is significant that the adsorptive capacity for each of the hydrocarbons studied was greatly affected by the presence of water vapor, but that the adsorptive capacity for water was not seriously impaired by the presence of the hydrocarbons.

APPLICATION OF DATA

The data and theory presented here can be applied to a number of problems relating to the design and operation of plants for dehydration of natural gas. For example:

A gas-dehydration plant has been designed to process one hundred million standard cubic feet per day of gas having a specific gravity of 0.612, which enters the plant at 1200 lb. per sq. in. gauge and at 85°F. This plant is equipped with an inlet scrubber, which will remove slugs of free water and condensate from the inlet gas. The dew-point of the inlet gas is found to be 65°F. Two pairs of two towers each are connected in parallel, so that while one pair is dehydrating the adsorbent material in the other pair is being regenerated. The inside dimensions of each of these towers is 3 ft. 0 in. in diameter by 28 ft. 0 in. high, and each tower is fitted with supporting trays, so that the effective depth of the adsorbent bed is 25 ft. 0 in. The towers are all packed with Florite, whose bulk density is 50 lb. per cubic foot.

Calculate: 1. The time interval required for the dew point of the outlet gas to rise to 32°F.

2. The quantity of gasoline (calculated as hexane) adsorbed at the end of 12 hours.

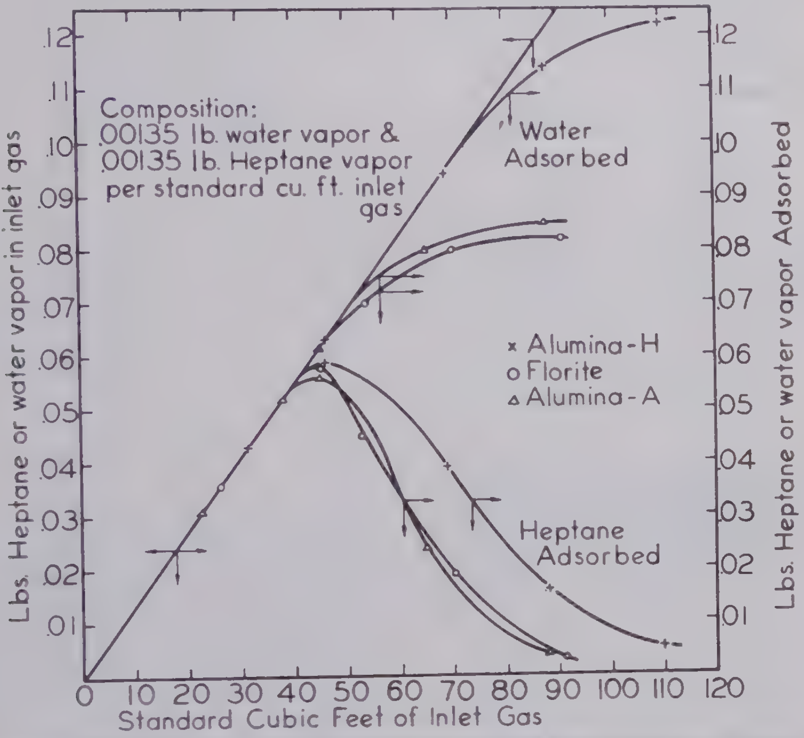

FIG. 5.—ADSORPTION OF HEPTANE AND WATER VAPOR ON THREE GRADES OF ALUMINA.

3. The quantity of gasoline adsorbed at the end of 8 hours.

Solution

1. From Brown's data[1] on supercompressibility:

Reduced temperature of inlet gas = 545/363 = 1.5
Reduced pressure of inlet gas = 1215/671 = 1.81
Supercompressibility factor = 0.833
Corrected inlet pressure = 1215/0.833 = 1460 lb. per sq. in. abs.
Vapor pressure of water at 65°F. = 0.307 lb. per sq. in. abs.
Mol fraction water vapor in inlet gas = 0.307/1460 = 0.00021

Mols per hour inlet gas = 100,000,000/(24 × 379) = 10,980

Water-vapor content = (10,980)(0.00021)(18) = 41.5 lb. per hr.

Vapor pressure of water at 32°F. = 0.0887 lb. per sq. in. abs.

Assuming a 50-lb. pressure drop across the towers:

Water vapor in the outlet gas = $\frac{(10{,}980)(0.0887)(0.84)(18)}{1165} = 12.35$ lb. per hr. when the dew point reaches 32°F.

Lacking specific adsorption data for this particular gas, the data reported here for hexane and water are used in the solution of Eq. 11:

$$\theta = \int_{X_s}^{X_\theta} \frac{S}{I - E}\,dX = S \int_{X_s}^{X_\theta} \frac{dX}{I - E} \qquad (11)$$

where

θ = time of adsorption cycle, hours

S = pounds Florite in two towers = $(2)(0.785)(3)^2(25)(50)$ = 17,650 lb.

X_s = pounds water adsorbed at start of cycle = 0

X_θ = pounds water adsorbed per pound Florite at time θ. From Fig. 5, the value of $X_\theta = 0.0712$ lb. per lb. Florite.

I = rate of flow of water vapor in inlet gas = 41.5 lb. per hr.

E = rate of flow of water vapor in outlet gas at time θ = 12.35 lb. per hr.

The data for X and $\frac{1}{I - E}$ are computed from Fig. 5 as shown in Table 3.

Plotting these values of X versus $\frac{1}{I - E}$, and performing a graphical integration, $\int_0^{0.0712} dX/(I - E)$ is found to be 0.0026. Substituting this value into Eq. 11:

$$\theta = (17{,}650)(0.0026) = 45.9 \text{ hours}$$

2. Assume that the hydrocarbons adsorbed are equivalent to commercial hexane, whose density is 5.53 lb. per gal., and calculating the water vapor charged to the towers in 12 hr., thus:

(12)(41.5) = 498 lb. per 12 hr.

498/17,650 = 0.0282 lb. water per lb. Florite

TABLE 3.—*Data Computed from Figure 5*

X	Partial Pressure of Water Vapor in Outlet Gas, Lb. per Sq. In. Abs.	E, Water Vapor in Outlet Gas, Lb. per Hr.	$I - E$	$\frac{1}{I - E}$
0.052	0	0	41.50	0.0241
0.054	0.001	0.141	41.36	0.0242
0.056	0.003	0.423	41.08	0.0243
0.058	0.006	0.845	40.65	0.0246
0.060	0.010	1.410	40.09	0.0249
0.062	0.018	2.540	38.96	0.0257
0.064	0.027	3.805	37.70	0.0265
0.066	0.039	5.500	36.00	0.0278
0.068	0.055	7.750	33.75	0.0297
0.070	0.0755	10.630	30.87	0.0324
0.0712	0.0887	12.350	29.15	0.0343

Fig. 5 shows that the vapor pressure of water in the outlet gas is virtually zero, and it follows that the dew point will be well below 0°F. Fig. 8 shows that when the water vapor adsorbed is 0.0282 lb. per pound of Florite, the hexane adsorbed is 0.048 lb. per pound of adsorbent, assuming a hydrocarbon-water ratio of 4 to 1, so the hydrocarbon recovery per 12 hr. is:

$$\frac{(17{,}650)(0.048)}{5.53} = 153.2 \text{ gal.}$$

or

153.2/50 = 3.06 gal. per million std. cu. ft.

3. If the cycle is shortened to 8 hr., the dew point of the outlet gas will be well below 0°F., and the water adsorbed is:

(8)(41.5) = 332 lb. per 8 hr.

332/17,650 = 0.0188 lb. water per lb. Florite

Fig. 8 also indicates that when the water vapor adsorbed is 0.0188 lb. per pound of adsorbent, the hexane adsorbed is 0.054 lb. per pound, so:

$$\frac{(17,650)(0.054)}{5.53} = 172.3 \text{ gal.}$$

or

$172.3/33.3 = 5.17$ gal. per million std. cu. ft.

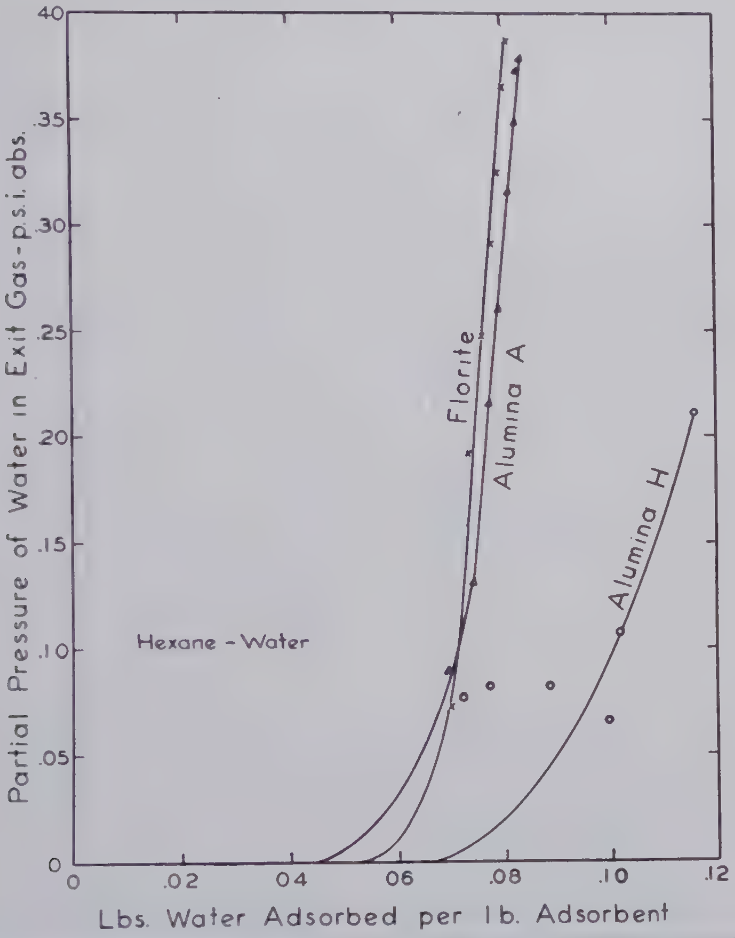

FIG. 6.—BATCH EQUILIBRIUM ADSORPTION OF WATER VAPOR IN PRESENCE OF HEXANE.

The results of these calculations approximate commercial operations reasonably well despite the fact that these data were obtained at atmospheric pressure on a mixture of lean natural gas saturated with water and commercial hexane vapors. It is obvious that more precise results could be obtained from equilibrium data obtained in the field. Equilibrium data for water vapor can be obtained from dew-point determinations provided that proper gas measurement facilities are available for each operating tower.

Commercial operation has confirmed two significant points brought out in this example; namely, (1) that the dew point rises very rapidly when the adsorbent approaches saturation, and (2), that greater hydrocarbon recovery is obtained from shorter operating cycles.

CONCLUSIONS

The following conclusions may be drawn from the results of this investigation:

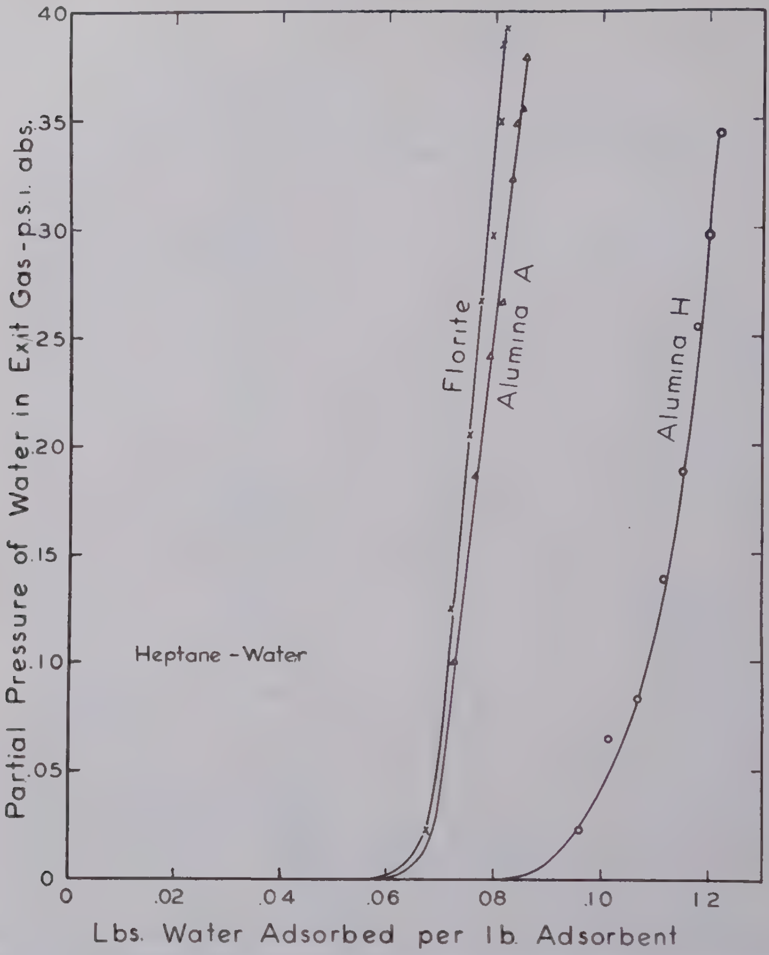

FIG. 7.—BATCH EQUILIBRIUM ADSORPTION OF WATER VAPOR IN PRESENCE OF HEPTANE.

1. The batch method is a comparatively simple and convenient means of studying the performance of solid adsorbents in gas-dehydration service. All complex variables including heat of adsorption are taken into account in a single batch curve.

2. The adsorption cycle is divided into three distinct phases; if maximum hydrocarbon recovery is desired, the adsorption cycle must be terminated early in the second phase.

3. The ratio of hydrocarbon to water adsorbed can be adjusted either by changing the length of the cycle or by varying the quantity of solid adsorbent.

4. Presence of heavier hydrocarbons in the inlet gas does not seriously affect the adsorptive capacity of Alumina-A, Florite or Alumina-H for water.

5. Presence of water vapor in the inlet gas does have a marked effect upon the adsorptive capacity of these three grades of alumina for the heavier hydrocarbons.

6. This investigation should be extended to high pressures, using gas that contains a complex mixture of the heavier hydrocarbons.

7. Batch adsorption data obtained in the field on any given gas should be extremely useful in the design and operation of de-

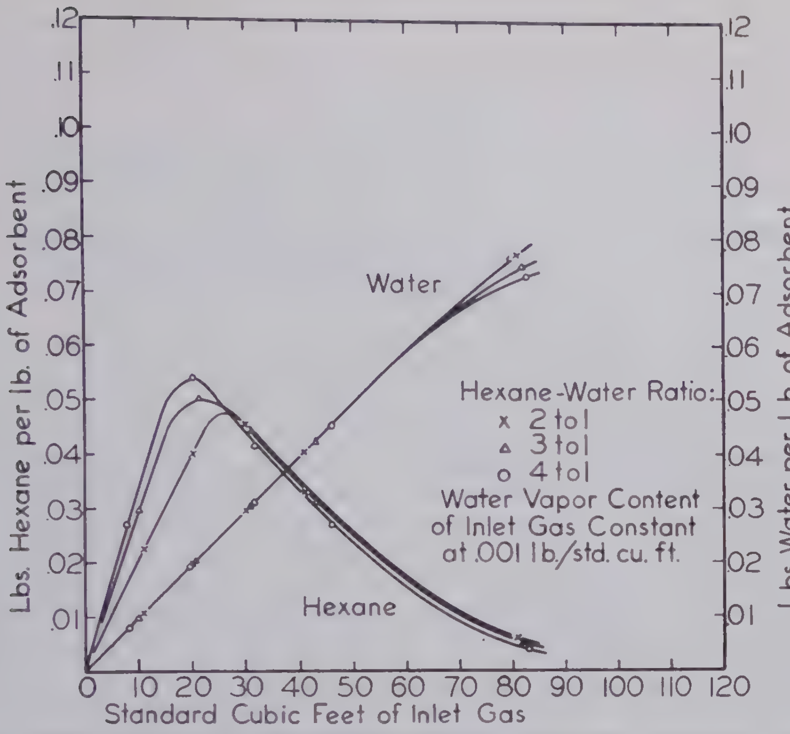

Fig. 8.—Effect of variable composition of inlet gas on quantity of hexane and water vapor adsorbed by florite.

hydration plants of the adsorption type for that particular gas.

8. The experimental data presented here should prove useful in the design and operation of dehydration plants when no field data are available.

Acknowledgment

This research, done in the laboratories of the School of Chemical Engineering at the University of Oklahoma, was sponsored by the Southern Natural Gas Co. through the University of Oklahoma Research Institute. The authors wish to thank Messrs. C. P. Rather, R. H. Burdick and C. E. Terrell, of the Southern Natural Gas Co., Dr. George L. Cross, Acting Director of the Research Institute, and Mr. W. H. Carson, Dean of the College of Engineering at the University of Oklahoma, for permission to publish this paper.

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Chapter III. Petroleum Economics

Sources, Disposition, and Characteristics of the Capital Employed by Thirty Oil Companies during the Nine-year Period 1934–1942

By Joseph E. Pogue,* Member A.I.M.E., and Frederick G. Coqueron*

(New York Meeting, February 1944)

Summary†

Prior to 1934, published information covering expenditures by oil companies for properties, plant, and equipment and the residual investments in the various segments of the petroleum industry was not readily available. This paper presents an analysis of the funds invested by a selected group of oil companies during the years 1934 through 1942, based on an extensive study of the individual records of 30 oil companies.

The sources, disposition, and characteristics of the capital employed by this group of companies are traced through a series of combined statements and appropriate charts, covering financial and operating data. The analysis of these statements not only constitutes a record useful for comparative purposes but also serves as a basis for a number of broad conclusions, as follows:

1. The petroleum industry generates the capital needed for its expansion almost entirely from its own operations and is therefore a singularly self-contained economic unit.

2. The long-term debt contained in the financial structure of the industry is small relative to the total capital employed, is less than the net working capital, and has increased but slightly during the period under review.

3. The capital expenditures of the group of 30 oil companies for 9 years amounted to 6.1 billion dollars, 58.3 per cent of which went into crude-oil producing facilities. The trend of this segment of expenditures has been downward since 1937. In 1942, expenditures for refining facilities increased sharply and for marketing facilities declined drastically.

4. The net working capital of the group increased 380 million dollars over the period, and the industry is in a favorable position of liquidity. The ratio of combined current assets to current liabilities was 3.21 at the close of the period.

5. The net income of the group displayed an upward trend for the period but with rather sharp cyclical fluctuations.

6. In 1942, Government funds entered the industry for the first time in substantial amounts and were utilized for the provision of war facilities needed for emergency use.

7. The group has paid out a relatively low percentage of net income in the form of dividends. For the period the average was 55 per cent of net income.

8. The rate of return on invested capital for the group averaged 6.4 per cent for the

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† A limited number of copies of the entire paper (Contribution No. 133) is available at Institute headquarters, New York.

period, compared with an average of 8.8 per cent for a group of over 1100 manufacturing companies. Integrated oil companies showed a lower rate of return than producing companies.

9. Combined net assets for the group totaled over 6 billion dollars at the end of 1942, of which 700 million dollars, or 12 per cent, were located outside the United States.

10. The combined net investment in properties, plant, and equipment of the group at Dec. 31, 1942, was distributed in the divisions of the business as follows: production, 45.6 per cent; transportation, 13.7 per cent; refining, 19.8 per cent; marleting, 18.7 per cent; and all other, 2.2 per cent.

11. The concentration of operations in large units is less than in many highly technological industries. The group in 1942 produced 54 per cent and refined 79 per cent of the totals for the country. Eighteen companies accounted for half of the nation's crude-oil production; and seven companies, for half of its refinery throughput.

12. The combined results for the group indicate a declining trend since 1937 in the capital expenditures per barrel of crude oil produced. The data also permit the construction of an index of crude-oil replacement cost, which has a rising trend for the same period.

13. The group increased its crude-oil production by 57 per cent and its refining throughput by 43 per cent between 1934 and 1942, as compared with an expansion of 25 per cent in gross fixed assets, 19 per cent in net fixed assets, and 11 per cent in borrowed and invested capital.

14. The combined statements indicate that the oil economy is functioning soundly and effectively.

Possibility of Converting the Large-diameter War Emergency Pipe Lines to Natural Gas Service after the War

By Sidney A. Swensrud,* Member A.I.M.E.

(New York Meeting, February 1944)

Summary†

THE 24-in. crude-oil line and the 20-in. petroleum-products line, built as a war emergency by the United States Government and running from points in Texas to the New York-New Jersey-Philadelphia area, were constructed only because of the inability during the war to continue normal ocean tanker movements from the Gulf Coast to the East Coast. The postwar disposition of these lines may be considered as one of the important problems of the postwar readjustments in the oil industry, if not the most important one. In the first place there appear to be many complications in keeping the lines in crude-oil or petroleum-products service. This conclusion was reached also in a study by T. E. Swigart, President of Shell Pipeline Corporation.[1]

Since the lines are too large for any one company to utilize, and since it appears likely that a surplus rather than a deficiency of tankers will exist after the war, most companies probably will feel that they can achieve lower costs and more satisfactory results from the resumption of tanker movements to the East Coast rather than by endeavoring to take over or utilize the capacity in the large pipe lines under some tariff-rate structure.

As for using the lines for making deliveries to the middle west or central eastern areas, it would appear that when the war is over and normal transportation arrangements can be resumed, there will be no need of any extra capacity for such deliveries. Therefore, the War Emergency lines could be utilized for this purpose only if privately owned pipe lines and other transportation facilities were to be displaced.

Against this rather unprepossessing prospect for use in petroleum or product service is the fact that at or near the source of the lines lie the greatest developed gas reserves in the world, for much of which there is at present no satisfactory market outlet; and at the other end of the lines lies one of the greatest concentrations of population in the world, which is not now served by natural gas. Those who have been fortunate enough to use natural gas can have little doubt of its desirability as a domestic fuel. An analysis of the market potentialities and comparison with other areas where natural gas is being distributed, and where it has displaced manufactured gas, makes it seem clear beyond question that the full capacity of both of the large-diameter lines could be fully utilized in this service, and this without creating any undue drain upon the gas reserves of the nation. On the basis of an estimated capacity of 100 to 120 billion cubic feet per year, the gas that might be marketed through these lines would amount to only 3 to 4 per cent of the total con-

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† A limited number of copies of the entire paper (Contribution No. 135) is available at Institute headquarters, New York.

[1] Postwar Uses of Pipeline for Petroleum Transportation presented at meeting of American Institute of Mining and Metallurgical Engineers, Feb. 24, 1944.

sumption of natural gas in the United States, and over a 10-year period it would constitute only about 1 per cent of the estimated present known reserves of natural gas in the country. The gas that could be put through the lines per year for use in the eastern area referred to would be less than one third of the quantity of gas burned annually in retorts in the state of Texas for the manufacture of carbon black, and less than one eighth of the quantity of gas used annually in that state for industrial purposes other than oil refining.

There would seem to be no question either but that the lines would be efficient gas carriers once the necessary extensions into gas-reserve areas had been made and the lines properly equipped with gas compressor stations, using natural gas as fuel. The direct cost of putting the gas through the lines all the way from one end to the other would be only about 5¢ per M cu. ft. The main costs would be the indirect items of taxes, depreciation and return on investment, which, together with reasonable allowances for gas storage costs, contingencies, etc., are estimated to bring the total throughput cost up to approximately 20¢ per M cu. ft. on the basis of a 75 per cent load factor, and if we then assume, as appears reasonable, that the cost of gas at the source would be approximately 5¢ per M cu. ft., the delivered cost in the east coast area would be around 25¢ per M cu. feet.

On the basis of such delivered cost, there appears to be no question but that attractive rates to consumers could be established, comparable with rates in other central eastern areas where conversion to natural gas has occurred.

Other conclusions reached in this study were as follows:

The use of both lines for gas service rather than only one would be an advantage from the standpoint of protection against emergency interruptions.

The gas delivered through the lines would displace the coal and oil now used to manufacture artificial gas, plus certain other quantities now used by consumers who would switch from other fuels to natural gas, but such loss of coal and oil volume would appear to be small in relation to the total volume of these products sold in the area.

By rearranging the oil-pumping and the gas-compressing facilities so as to increase the number of stations on each line, one of the lines could be used for oil deliveries in the event of another emergency, while still delivering large quantities of gas through the other line.

Chapter IV. Production

Introduction

By Winthrop P. Haynes,* Member A.I.M.E.

The symposium on production for the year 1943 contains few papers on the foreign situation. It has always been the policy of officers in charge of the symposium to refrain from publishing information that might possibly injure national or private interests. At the close of the war we hope again to publish full and accurate records of production abroad.

A noteworthy feature of the reports on Texas this year is the map on page 469, which shows the districts covered by the statistics.

Excerpts from Circular to Authors

In order to facilitate interpretation of the data in this chapter, we print the following excerpts from the Circular to Authors.

The field is the unit in this tabulation. In cases of fields extending across State boundaries, such as Rodessa, it is suggested that each State author treat the section of the field in his State as a unit, and by a footnote indicate that the field extends into an adjacent State.

Each place in the table may represent one of three possibilities; either the proper entry is determinable and can be supplied by the author, or an approximate figure can be supplied which is the author's best guess and should be entered followed by an *x*, or it does not apply to the particular field and the space is left blank. Contributions of great value may be made by the author in many cases where entries are not subject to precise determination. In such cases the author should use his good judgment and make the best entry possible under the circumstances.

The entry of a zero is a positive declaration, and it is an important declaration where it is in order.

It is thought that the nearest whole numbers are sufficiently accurate for our purposes except as to percentage of sulphur in oil. If an author desires to report any other figures to tenths, he may do so.

The quantity of gas produced should include, where possible, gas sold or otherwise marketed, and gas blown into the air, burned as flares or otherwise wasted. Segregation of these figures would be interesting if the authors can make such segregation. In any event, the figures should represent as nearly as possible the total quantity of gas removed from the reservoir.

Under the columns on "Depth," the average depth to the top of the productive zones and to the bottom of the productive wells, when subtracted, should give the approximate thickness of the productive zone. For fields where this is not true because of unusually high dip or for some other reasons, it is suggested that the authors indicate in their text the approximate average thickness of the productive zone.

The net thickness of the producing formation should be the thickness of the producing zone, less the estimated amount to cover the portions of the zone that do not yield oil, such as dense shales, etc. It is recognized that for some fields the authors can only make rough guesses; in such cases, they should enter their best estimate followed by an *x*. Average production per acre-foot need not be reported as it can be calculated by those interested from the figures given.

In classifying wells as to producing methods, enter all wells that are not "flowing" in the column headed "Artificial Lift." If possible, add footnotes to indicate whether the lift is "pumping," "gas lift" or "air lift."

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It is recognized that for many fields it would be very difficult to determine accurately the quantity of each gravity of oil produced. However, the approximate weighted average gravity that will be representative of the total production can be determined sufficiently accurately to constitute significant information.

FOOTNOTES TO COLUMN HEADINGS—TABLE 1

[a] All fields to be listed alphabetically and if by counties the latter also in alphabetical order. If the field is a gas field, or is primarily a gas-producing field, indicate by asterisk immediately after the name of the field, as, for example, Katy,* *Waller*.

[b] Total area in surface acres in the field proved for production of oil and/or gas.

[c] Total production in barrels of oil and/or distillate or condensate; and show by footnote, where possible, the amount of distillate or condensate production.

[d] Applies only to areas in which shutdown days are ordered by a regulatory body. In such instances, show total number of days on which production was permitted during year.

[e] Volume of gas produced from the field and not returned to the reservoir.

[f] Include all original completions, but exclude workovers and wells deepened or plugged back. *Abandoned* refers only to wells abandoned after having produced oil and/or gas and is not to include wells abandoned without having secured production.

[g] A well producing both oil and gas is classified as an oil well, unless it has been designated as a gas well by the State regulatory agency. Gas wells are wells producing gas only, wells producing condensate or distillate, and wells producing some oil but classified as gas wells by the State regulatory agency.

[h] Show type of operation as indicated by the following symbols: P, pressure maintenance; G, gas injection; W, water injection; C, cycling.

[i] Show weighted average gravity A.P.I. at 60°F. as oil is delivered to the pipe lines, and percentage of sulphur, if any, in the oil. Where oils from more than one stratum are commingled and delivered into the pipe line at a gravity of 26 to 26.9, show as 26°, etc.

[j] Show name of producing formation, and show its age by abbreviation as follows: Cam, Cambrian; Ord, Ordovician; Sil, Silurian; Dev, Devonian; Mis, Mississippian; MisL, Lower Mississippian; MisU, Upper Mississippian; Pen, Pennsylvanian; Per, Permian; Tri, Triassic; Jur, Jurassic; CreL, Lower Cretaceous; CreU, Upper Cretaceous; Eoc, Eocene; Olig, Oligocene; Mio, Miocene; Pli, Pliocene.

[k] Show character of formation by code letter as follows: A, anhydrite; C, chalk; Cg, conglomerate; Ch, chert; CR, cap rock; D, dolomite; Da, arkosic dolomite; Gw, granite wash; Sh, shale; L, limestone; LS, limestone, sandy; OL, oölitic limestone; S, sandstone.

[l] Figures represent ratio of pore space to total volume of net reservoir rock expressed in per cent. P indicates reservoir rock is of porous type, but ratio is not known by the author. Cav indicates that the reservoir rock is of cavernous type; and Fis, fissure type.

[m] Show actual depth to top of producing stratum. If producing zone is a series of interbedded sands and shales, and the sands are all productive or capable of producing, show the depth to top of top sand member.

[n] Show actual average thickness that is producing or known to be productive. If, for example, average thickness of productive zone above water level is 50 feet, show 50 feet, even though wells are completed in only upper 10 or 15 feet of zone.

[o] A, anticlinal; AF, anticlinal with faulting as important factor; Af, anticlinal with faulting as minor factor; AM, accumulation due to both anticlinal and monoclinal structure; D, dome; DS, salt dome; H, strata are horizontal or nearly horizontal; MC, monocline with accumulation due to change in character of stratum; MF, monocline-fault; MI, monocline with accumulation against igneous barrier; ML, monocline-lens; MU, monocline-unconformity; MP, monocline with accumulation due to sealing at outcrop by asphalt; N, nose; S, syncline; T, terrace; TF, terrace with faulting as important factor.

[p] Show name of deepest stratigraphic zone tested and total depth of well which tested such zone, whether it is deepest well in field or not.

x *Correct entry not determinable.*

Oil and Gas Development in South Arkansas in 1943

By Alec M. Crowell,* Member A.I.M.E., and Harry P. McClintock*

Production of oil and gas condensate from the 45 oil and gas fields of South Arkansas increased for the eighth consecutive year, the production for 1943 being 27,605,647 bbl. Six new pools were discovered during 1943, bringing the state's crude oil and condensate reserve to 475 million barrels, a net increase of 70 million barrels for the year. The gross increase in proven reserve was 98 million barrels, from which, of course, is subtracted production of approximately 28 million barrels to reach the net figure of 70 million barrels.

There were 35 more wildcats in 1943 than in 1942, and 29 more wells were drilled in fields of the state. Sixteen companies operated exploratory crews during the year for a total of 677 crew weeks, divided as follows: 563 weeks seismograph, 111 weeks gravity and 3 weeks core drill. There was a decided increase in gravity work and a decrease in seismic work. The year started with 15 seismic crews and ended with 5 seismograph and 2 gravimeter crews.

Geologically, it is interesting that the number of wells bottomed in Gulf, Comanche, and Jurassic strata were near equal for the year 1943. During 1942 Jurassic was much higher than the other two. However, Jurassic still led in wildcats for the year 1943.

Abandoment of wells in the stripper areas of the state reached about the same figure for the year 1943 as for the year 1942; that is, 145 wells were permanently abandoned. However, 243 wells were drilled in 1943, as against 184 for the previous year. The completions for the year were divided into 103 dry holes, 137 oil and condensate wells and 3 dry gas wells.

Among new developments perhaps the most significant was the pressure-maintenance project for the Midway field of Lafayette County, which is utilizing fresh water as the maintenance medium. This is the first fresh-water pressure-maintenance operation during primary production of an oil field in the United States. The operator of the project, Barnsdall Oil Co., estimates that the ultimate recovery of oil from this field will be increased from 32.5 to 65 million barrels.

The Midway pool is of the dissolved-gas type, but a similar project is getting underway for the Magnolia field, Columbia County, a pool of the gas-cap and water-drive type.

Dual completion of wells, on concurrent production from two productive zones through a single well bore, became common practice in South Arkansas during the year. As the year ended, some 50 wells had been dually completed and it was estimated that the first 37 of these wells represented a saving of more than 2¼ million dollars and a saving in steel of 7000 tons.

The majority of the wells dually completed were those reaching depths in the neighborhood of 9000 ft. below the surface and initially productive there. Selective completion at lesser depths in the same well bore proved mechanically feasible and economically sound.

The year was marked by the successful completion and placing into operation of three large natural-gas desulphurization

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units in the state. Natural gas containing hydrogen sulphide to a concentration of 15 per cent is now being successfully treated for the removal of this hydrogen sulphide, as well as of carbon dioxide. These three plants were processing, as the year ended, approximately 150 million cubic feet of sour gas daily, manufacturing more than 200,000 gal. of hydrocarbon products from the gas, and all of the dry sweet gas residue was being utilized by some 13 war industries and military facilities as industrial and domestic fuel.

The Southern Acid and Sulphur Co., Inc., of St. Louis, Mo., completed and placed in operation a sulphur-reclamation plant on the discharge of the McKamie Gas Cleaning Company's plant in the McKamie field, Lafayette County, Arkansas. The Southern Acid and Sulphur Co. processes the acid gas residue from the gas-desulphurization unit and was recovering as the year ended 65 tons of pure sulphur daily. This represents a recovery of 97 per cent of the sulphur contained in the natural gas.

Pressure-production behavior on 20 of the 33 oil and condensate pools operating under state control reflected a good account of the Oil and Gas Commission's policy of optimum production practice. Table 2 sets out the pool name, subsea depth, productive acreage, 1943 production and the daily average change in reservoir pressure.

NEW POOLS

West Atlanta.—On July 4, 1943, Tide Water Associated-Seaboard's A. O. Young No. 1 well, NE¼ SW¼, sec. 18, T. 18 S., R. 19 W., Columbia County, Arkansas, was completed successfully as a Cotton Valley and Smackover lime dual completion.

The Cotton Valley was perforated from 7210 to 7216 ft. and completed through the casing. Initial production was 387 bbl. of 42° A.P.I. gravity oil per day on a ¼-in. choke. Initial gas-oil ratio was 500 cu. ft. to the barrel, while initial bottom-hole pressure was 3080 lb. per sq. in. Production for 1943 was 17,652 barrels.

The Smackover lime was completed through the tubing and produced at an initial rate of 694 bbl. of 44° A.P.I. gravity oil per day on a ¼-in. choke with a gas-oil ratio of 1291 cu. ft. per barrel and bottom-hole pressure of 3483 lb. per sq. in. Structurally this pool consists of an elongated east-west anticline with the discovery well 1½ miles due west of the Atlanta pool. Since the two pools have the same water level of 8000 ft. subsea, it is possible that they may connect. Production for 1943 was 26,284 barrels.

An interesting feature of this well is the successful testing of the Cotton Valley, since the Schlumberger logs show practically all Atlanta wells as having good Cotton Valley possibilities.

Hampton.—On April 8, 1943, Calhoun County, had its first oil well completed when Placid Oil Company's Freeman-Smith No. 4 well, NE¼ NW¼, sec. 2, T. 15 S., R. 14 W., began pumping at an initial daily rate of 38 bbl. of 18° A.P.I. gravity oil. The well was drilled to and tested in the Smackover lime at a total depth of 4420 ft. but was plugged back to the Meakin sand of the Upper Cretaceous, where casing was perforated from 2514 to 2524 ft. and from 2534 to 2538 ft. Since offset locations have been tested dry, it is thought that the discovery is of a minor nature. Production for 1943 was 4471 barrels.

Mt. Holly-Cotton Valley.—On July 27, 1943, the Cotton Valley series of the Mt. Holly pool proved to be productive when the Atlantic Refining Company's Lewis No. 1 well was successfully completed in this horizon. After perforating casing from 6112 to 6118 ft., the well tested initially 168 bbl. of 34° A.P.I. gravity oil per day on a $\frac{3}{16}$-in. choke, with a gas-oil ratio of

TABLE I.—*Oil and Gas Production in South Arkansas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil And/or Gas Wells[f]		
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
1	Atlanta, *Columbia*	1938	880	3,772,028	910,608	5,133	1,425	23	1	1
	Atlanta-West, *Columbia*									
2	Cotton Valley[1]	1943	40	17,652	17,652	8	8	1	1	0
3	Reynolds	1943	80	26,284	26,284	339	339	2	2	0
4	Big Creek, *Columbia*	1939	160	142,113	29,058	3,644	817	1	0	0
5	Bradley, *Lafayette*	1925	80	186,705	0	*x*	0	6	0	0
6	Buckner, *Columbia, Lafayette*	1937	1,170	4,055,122	661,365	983	160	29	1	0
7	Camden (Bragg), *Ouachita*	1934	10	37,848	(Abd. 1940)	*x*	0	1	0	0
8	Champagnolle, *Union*	1927	2,030	15,427,568	247,056	*x*	*x*	251	8	13
9	Columbia, *Columbia*[2]	1942	40	9,529	9,529	215	215	1	0	0
	Dorcheat, *Columbia*									
10	Cotton Valley[1]	1942	1,760	369,250	316,914	6,128	5,542	20	10	0
11	Reynolds	1939	2,000	2,160,305	461,874	20,909	4,677	36	10	0
12	El Dorado-East, *Union*	1922	1,400	9,799,559	188,920	*x*	*x*	211	8	6
13	El Dorado-South, *Union*	1920	7,980	49,047,546	317,939	*x*	*x*	1,116	0	11
14	Falcon, *Nevada*[3]	1938								
15	Fouke, *Miller*	1940	485	1,004,183	477,026	26*x*	2*x*	24	11	1
16	Garland City, *Miller*	1932	290	2,158,278	85,971	*x*	*x*	28	0	1
17	Hampton, *Calhoun*	1943	40	4,471	4,471	*x*	*x*	1	1	0
18	Haynesville, *Columbia*[4]	1942	720	197,597	196,537	103	103	10	9	0
19	Irma, *Nevada*	1921	900	7,445,460	217,160	*x*	*x*	150	0	0
20	Lewisville (Stamps), *Lafayette*	1939	400	593,888	55,064	367*x*	33*x*	19	0	1
21	Lisbon, *Union*	1925	2,700	6,874,710	52,204	*x*	*x*	356	0	11
	Macedonia, *Columbia*									
22	Cotton Valley[1]	1942	2,240	476,425	458,855	6,290	5,992	18	9	0
23	Reynolds	1940	2,720	895,379	386,176	12,000	5,914	29	10	0
	Magnolia, *Columbia*									
24	Cotton Valley	1943	40	1,151	1,151	1	1	1	1	0
25	Reynolds	1938	4,414	30,714,436	5,999,674	28,366	6,234	116	0	2
	McKamie, *Lafayette*									
26	Cotton Valley	1942	160	27,865	12,230	7	3	1	0	0
27	Reynolds	1940	2,780	2,031,179	352,758	15,497	2,777	19	0	0
28	Midway, *Lafayette*	1942	1,612	3,392,500	2,170,253	874	552	42	7	2
29	Mt, Holly (McDonald), *Ouachita*	1929	60	117,085	(Abd. 1931)	*x*	0	6	0	0
	Mt, Holly, *Union*									
30	Cotton Valley	1943	120	6,108	6,108	2	2	3	3	0
31	Reynolds	1941	360	349,952	210,213	1,779	919	10	5	0
32	New London, *Union*	1942	760	421,557	353,592	199	170	19	7	0
	Nick Springs, *Union*									
33	Cotton Valley	1943	10	6,017	6,017	0.6	0.6	1	1	0
34	Travis Peak	1940	130	675,754	60,228	268*x*	18*x*	14	0	4
35	Patton, *Lafayette*	1941	80	33,584	8,065	81	13	2	0	0
36	Rodessa, *Miller*	1937	2,150	6,820,863	213,342	44,017	3,892	123	0	7
	Schuler, *Union*									
37	Cotton Valley	1942	640	611,336	409,687	1,303	798	15	8	0
38	Jones Sand[5]	1937	2,964	29,510,044	3,957,374	50,219	8,923	146	0	0
39	Morgan Sand	1937	300	2,705,243	197,547	2,166*x*	148*x*	14	0	0
40	Reynolds	1937	806	4,753,349	744,231	6,795	660	16	0	1
41	Schuler-East, *Union*	1941	340	434,038	202,945	820	173	6	0	0
42	Smackover, *Ouachita, Union*		25,760			*x*	*x*	3,761	1	19
43	Heavy	1922	16,000	342,159,535	3,849,485	*x*	*x*			

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[b] Footnotes to column heads and explanation of symbols are given on page 270.

[1] Dually completed in both Lime and Cotton Valley. [2] Temporarily shut in by P.A.W.

[3] Production included in East ElDorado, other data not available. [4] Extension of Haynesville pool from Louisiana.

[5] Gas-recycling plant; 93 wells of unit not producing.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity, A.P.I. at 60°F.	Sulphur, Per Cent	Name of Age[f]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
1	21	1	0	3,821	3,364		42.6	0.49	Reynolds, Jur	OL	15	8,202	30	A	Smackover	8,332
2	1	0	0	3,085	*x*		41.5	0.29	Cotton Valley, Jur	S	15	7,210	14	AL	Smackover	8,356
3	2	0	0	3,483	3,390		43.4	0.49	Reynolds, Jur	OL	20	8,294	38	A	Smackover	8,356
4	0	0	1	3,723	3,303		66.2	0.05	Reynolds, Jur	OL	12.5	7,956	38	A	Smackover	7,999
5	0	0	0	*x*	*x*		26	0.43	Buckrange, CreU	S	Por	2,785	5	A	Paluxy	3,555
6	7	22	0	3,195	2,495		32.3	1.87	Reynolds, Jur	OL	20	7,200	30	A	Smackover	7,444
7	0	0	0	*x*	*x*		16	2.56	Nacatoch, CreU	S	25	1,356	13	ML	Travis Peak	2,500
8	0	72	0	*x*	*x*		22.3 34	2.00 1.42	Tokio, CreU Hosston, CreL	S	30	2,780 3,340	15	NL	Eagle Mills	6,911
9	1	0	0	3,750	*x*		66.4	0.14	Reynolds, Jur	OL	15	8,030	25	A	Smackover	8,150
10	20	0	0	3,400	2,900*x*		67.3 44.7	0.02 0.35	Cotton Valley, Jur	S	15	7,850	25	AL	Smackover	9,028
11	36	0	0	4,243	3,040		54	0.39	Reynolds, Jur	OL	20	8,815	40	A	Smackover	9,028
12	0	60	3	*x*	*x*		20.5	1.92	Nacatoch, CreU	S	25	2,170	10	TL	Cotton Valley	6,003
13	0	176	0	*x*	*x*		32.5	1.11	Nacatoch, CreU	S	25	2,100	20	ANL	Smackover	7,820
14							13		Nacatoch, CreU	S						
15	2	21	0	1,485	*x*		32.1	1.26	Paluxy, CreL	S	25	3,583	25	F	Smackover	9,550
16	0	8	0	*x*	*x*		31.7	1.26	Paluxy Rodessa, CreL	S	Por	2,925 4,200	10	ML	Smackover	7,906
17	0	1	0	*x*	*x*		13.5	4.00	Meakin, CreU	S	25	2,514	24	AL	Smackover	4,420
18	7	3	0	2,344	2,014		41.4	0.60	Pettit, CreL	OL	18	5,462	15	A	Pettit	5.590
19	0	73	0	*x*	*x*		14.1	2.70	Nacatoch, CreU	S	25	1,150	27	AF	Travis Peak	3,735
20	0	18	0	1,450*x*	*x*		42.6	0.63	Blossom, CreU Rodessa, CreL	S OL	17	3,400	20	TF	Smackover	7.420
21	0	132	0	*x*	*x*		34.0	1.08	Nacatoch, CreU	S	25	2,100	20	ML	Smackover	6,861
22	18	0	0	3,400	2,900*x*		66.6 43.7	0.21 0.43	Cotton Valley, Jur	S	14	7,900	12	AL	Smackover	9,020
23	29	0	0	4,130	3,427		61.5	0.13	Reynolds, Jur	OL	20	8,870	75	A	Smackover	9,020
24	1	0	0	*x*	*x*		38.1	*x*	Cotton Valley, Jur	S	15	5,870	10	AL	Smackover	7,824
25	104	9	0	3,465	2,972		38	0.89	Reynolds, Jur	OL	20	7,350	100	A	Smackover	7,824
26	0	1	0	2,831	*x*		43.5	0.38	Cotton Valley, Jur	S	15	7,255	10	AL	Eagle Mills	9,980
27	18	0	0	4,365	4,132		57.9	0.24	Reynolds, Jur	OL	20	9,125	106	A	Eagle Mills	9,980
28	37	3	0	2,920	2,643	PW	36.2	1.32	Reynolds, Jur	OL	25	6,340	75	Af	Smackover	6,750
29	0	0	0	*x*	*x*		30	*x*	Hosston, CreL	S	30	2,800	7	ML	Travis Peak	3,378
30	3	0	0	*x*	*x*		42.5	0.27	Cotton Valley, Jur	S	18	6,112	6	AL	Smackover	7,373
31	9	1	0	3,180	3,036		40	0.77	Reynolds, Jur	OL	20	7,146	26	A	Smackover	7,373
32	4	15	0	2,650*x*	2,220*x*		30.8	1.88	Cotton Valley, Jur	S	18	5,700	25	AF	Smackover	6,100
33	0	1	0	*x*	*x*		36	*x*	Cotton Valley, Jur	S	23.2	4,790	3	AL	Smackover	6,819
34	0	9	0	1,600	*x*		37.5	0.95	Hosston, CreL	S	30	3,153	15	AF	Smackover	6,819
35	2	0	0	4,380	*x*		47	0.60	Reynolds, Jur	OL	16	9,312	30	A	Smackover	9,503
36	0	43	10	2,800	*x*		42.7	0.34	Rodessa, CreL	S-Ls	25	6,050	25	AF	Rodessa	6,514
37	15	0	0	3,090	2,500*x*		45.4	*x*	Cotton Valley, Jur	S	16	6,900	10	AL	Smackover	8,328
38	38	93^5	0	3,520	1,454	G	34.6	1.40	Cotton Valley, Jur	S	17	7,530	42	A	Smackover	8,328
39	0	14	0	2,000*x*	*x*		40.9	0.54	Cotton Valley, Jur	S	16	5,500	15	AL	Smackover	8,328
40	13	1	0	3,550	3,280		36.8	0.91	Reynolds, Jur	OL	15	7,600	26	A	Smackover	8,328
41	5	1	0	2,509	2,394*x*		45.2	0.36	Cotton Valley, Jur	S	25	5,580	14	AL	Smackover	7,702
42	0	1,585	0													
43				*x*	*x*		19 23	2.02 2.36	Nacatoch Graves, CreU Tokio	S	25	2,000 2,450 2,600	40	Af	Eagle Mills	7,255

351 cu. ft. per barrel. Production for 1943 was 6108 barrels.

Wisinger Pool.—On Oct. 1, 1943, the Hill sand series proved to be productive at the N. H. Wheless-Wisinger No. 1 well in the center of the NW¼ SE¼, sec. 9, T. 20 S., R. 27 W., Miller County. This wildcat, when tested from 5940 to 5970 ft., produced 48.5° gravity oil at the rate of 138 bbl. daily through 11/64-in. choke.

TABLE 1.—(*Continued*)

				Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil And/or Gas Wells[f]		
									1943	
Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned
44	Light	1922	9,600	56,491,273	575,660	*x*	*x*			
45	Snow Hill	1936	160	281,861	32,687	*x*	*x*			
46	Stephens, *Columbia, Nevada, Ouachita*	1922	3,000	7,583,030	166,825	*x*	*x*	312	0	0
47	Stephens-Smart, *Columbia*	1941	1,340	1,842,941	1,397,762	375*x*	274*x*	71	48	0
48	Texarkana, *Miller*[2]	1942	160	21,782	10,092	694	347	1	0	0
49	Troy, *Nevada*	1936	500	2,705,528	338,110	*x*	*x*	51	0	0
50	Urbana, *Union*	1930	500	7,829,625	699,168	*x*	*x*	85	0	0
51	Village, *Columbia*	1938	730	2,008,815	439,300	8,270	1,338	13	0	0
52	Wilmington, *Union*	1943	40	1,873	1,873	*x*	*x*	1	1	0
53	Wisinger, *Miller*[2]	1943						1	1	0
54	Woodley, *Union*[3]	1922								

TABLE 1.—(*Continued*)

	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.			Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
Line Number	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943	Secondary Recovery[h]	Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name of Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.,[n]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
44				*x*	*x*		21 27	1.77 2.24	Nacatoch } , CreU Meakin }	S	25	{ 2,000 } { 2,275 }	30	ALf	Igneous	7,973
45				*x*	*x*		36	1.08	Reynolds, Jur	OL	25	4,800	30	AF	Eagle Mills	5,708
46	0	202	0	*x*	*x*		13 31	2.87 1.60	Nacatoch } , CreU Buckrange }	S	25	{ 1,500 } { 2,100 }	15	NLF	Smackover	6,053
47	0	71	0	1,625*x*	*x*		32.6	1.80	Hosston, CreL	S	30	3,390	10	A	Smackover	5,965
48				3,418	3,307		70	0.3	Reynolds, Jur	OL	14	7,348	51	A	Smackover	7,700
49	0	44	0	*x*	*x*		{ 14 { 22	2.24 2.51	Nacatoch } , CreU Tokio }	S	25	{ 1,243 } { 2,160 }	10	F	Eagle Mills	6,143
50	0	68	0	*x*	*x*		29.7	1.39	{ Nacatoch, CreU } { Hosston, CreL }	S	25	{ 2,270 } { 3,560 }	10	A	Cotton Valley	4,501
51	13	0	0	3,350	3,092		41.1	0.80	Reynolds, Jur	OL	20	7,390	20	A	Smackover	7,603
52	0	1	0	*x*	*x*		16	*x*	L Graves, CreU	S	25	2,770	10	A	Smackover	5,836
53	1	0	0	*x*	*x*		48.5	*x*	Rodessa (Hill sand), CreL	S	25	5,944	20	A	Rodessa	6,997
54									Nacatoch, CreU	S						

The gas-oil ratio originally was 11,200 cu. ft. to the barrel, but steadily increased with an increase in the gravity of the oil. The well was classed as a gas-distillate well by the Petroleum Administration for War and closed to production until a second well could be drilled. The second well is the M. E. Luse No. 1, located by the Gerhig Company of Arkansas on 120 acres comprising the S½ SW¼, sec. 10, T. 20 S., R. 27 W., and the W½ of fractional sec. 15, T. 20 S., R. 27 W. This lease lies against the Louisiana state line. There was no production during 1943.

TABLE 2.—*Pressure Production*

Pool	Sub-sea Depth, Ft.	Producing Area, Acres	Production in 1943, Bbl.	Daily Average Pressure Change[1]
Atlanta	7,950	880	910,034	0
Atlanta—West	7,990	80	25,921	−0.255
Big Creek	7,700	160	28,933	−0.216
Buckner	6,900	1,170	662,286	−0.068
Columbia	7,793	40	9,589	0
Dorcheat—Lime	8,650	2,000	841,429	−0.698
Dorcheat—Cotton Valley	7,660	1,760	532,699	−0.726
Haynesville	5,200	720	202,070	−0.904
Macedonia	8,650	2,520	285,840	−0.674
Magnolia	7,150	4,453	6,005,226	−0.200
McKamie—Lime	9,000	2,880	364,558	+0.019
Midway	6,050	1,612	2,170,528	−0.249
Mt. Holly—Lime	6,910	360	210,918	−0.290
New London	5,570	760	354,786	−0.904
Schuler—East	5,350	340	204,660	−0.025
Schuler—Cotton Valley	6,646	640	410,783	−0.548
Schuler—Jones	7,300	2,964	3,959,909	−0.011
Schuler—Reynolds	7,350	606	747,244	−0.151
Texarkana	7,000	160	10,092	−0.068
Village	7,050	520	436,952	−0.255

[1] Pounds per square inch change in reservoir pressure as determined by actual gauge.

Wilmington.—On Nov. 26, 1943, Kerlyn Oil Co. (Phillips) Frost No. 1 well, NW¼ SE¼ NE¼, sec. 9, T. 17 S., R. 13 W., Union County, was completed successfully in the Lower Graves sand. The sand was perforated with 16 shots from 2770 to 2774 ft. and produced 158 bbl. of oil in 16 hr. on the pump. The oil was 16° A.P.I. gravity, the spacing one well to 40 acres, and as the year ended no pipe line was available.

Magnolia-Cotton Valley.—On Dec. 1, 1943, Hollyfield and McFarlane completed the first Cotton Valley well in the Magnolia field of Columbia County. The well was Rowe No. 1, SW¼ SW¼, sec. 16, T. 17 S., R. 20 W., which it was necessary to abandon in the limestone formation. The well was plugged back to 6000 ft. and perforated from 5870 to 5880 ft. As the year ended the well had produced 1151 bbl. of 42° A.P.I. gravity crude oil and a pumping unit was being installed.

The opening of Cotton Valley production on the northwest edge of the Magnolia field may lead to some interesting developments during the year 1944.

REGULATION OF PRODUCTION

The Arkansas Oil and Gas Commission continued to control production on an optimum rate basis through a greater concentration on the system of true operating gas-oil ratios for each field. Volumetric proration began to take precedence over the old acre-pound basis.

ACKNOWLEDGMENTS

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TABLE 3.—*Summary of Drilling Operations in South Arkansas*

Important Wildcats Drilled in 1943

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Tp.	Rge.			
1	Ashley	2	19 S	7 W	6,865	Terrace deposits	Eagle Mills
2	Bradley	28	15 S	10 W	6,301	Terrace deposits	Eagle Mills
3	Bradley	12	16 S	10 W	5,390	Terrace deposits	Smackover lime
4	Calhoun	22	16 S	13 W	5,303	Alluvium	Smackover lime
5	Calhoun	14	16 S	13 W	6,927	Alluvium	Eagle Mills
6	Calhoun	14	16 S	13 W	5,082	Alluvium	Smackover lime
7	Calhoun	30	14 S	14 W	4,537	Terrace deposits	Smackover lime
8	Calhoun	35	14 S	14 W	2,564	Terrace deposits	Meakin sand (Ozan)
9	Calhoun	12	15 S	14 W	4,615	Alluvium	Smackover lime
10	Calhoun	11	15 S	14 W	4,590	Alluvium	Smackover lime
11	Calhoun	2	15 S	14 W	4,420	Terrace deposits	Smackover lime
12	Calhoun	2	15 S	14 W	2,566	Alluvium	Meakin sand (Ozan)
13	Calhoun	8	15 S	14 W	4,699	Alluvium	Smackover lime
14	Calhoun	34	15 S	14 W	3,510	Alluvium	Cotton Valley
15	Calhoun	12	16 S	14 W	3,146	Alluvium	Hosston
16	Calhoun	12	16 S	14 W	5,150	Alluvium	Smackover lime
17	Calhoun	35	14 S	15 W	4,711	Terrace deposits	Smackover lime
18	Calhoun	13	13 S	16 W	3,096	Alluvium	Eagle Mills
19	Calhoun	2	13 S	16 W	2,250	Alluvium	Meakin sand (Ozan)
20	Chicot	3	19 S	1 W	7,210	Terrace deposits	Eagle Mills
21	Cleveland	21	10 S	9 W	4,606	Jackson	Paleozoic
22	Cleveland	25	11 S	9 W	4,248	Terrace deposits	Igneous
23	Cleveland	27	10 S	11 W	3,745	Jackson	Paleozoic
24	Columbia	18	18 S	19 W	8,356	Claiborne	Smackover lime
25	Columbia	8	17 S	18 W	7,410	Claiborne	Smackover lime
26	Columbia	18	18 S	19 W	8,356	Claiborne	Smackover lime
27	Columbia	23	17 S	21 W	8,116	Claiborne	Smackover lime
28	Columbia	14	16 S	21 W	7,659	Claiborne	Smackover lime
29	Columbia	9	20 S	21 W	6,337	Claiborne	Hosston
30	Columbia	10	17 S	22 W	8,306	Claiborne	Smackover lime
31	Columbia	9	20 S	22 W	6,315	Terrace deposits	Hosston
32	Columbia	10	19 S	23 W	10,600	Terrace deposits	Smackover lime
33	Columbia	10	16 S	20 W	6,944	Terrace deposits	Smackover lime
34	Desha	23	7 S	1 E	4,651	Alluvium	Paleozoic
35	Hempstead	34	13 S	26 W	4,938	Terrace deposits	Igneous
36	Lafayette	30	16 S	24 W	5,217	Claiborne	Pettit
37	Lafayette	3	20 S	24 W	6,326	Terrace deposits	Hosston
38	Miller	4	16 S	26 W	7,909	Alluvium	Smackover lime
39	Miller	4	15 S	27 W	6,695	Alluvium	Eagle Mills
40	Miller	9	20 S	27 W	6,997	Claiborne	Hosston
41	Miller	1	19 S	28 W	6,706	Claiborne	L. Glen Rose
42	Monroe	22	3 N	3 W	3,164	Alluvium	Paleozoic
43	Nevada	21	14 S	20 W	5,577	Claiborne	Smackover lime
44	Nevada	5	14 S	20 W	5,268	Claiborne	Smackover lime
45	Nevada	18	14 S	22 W	7,180	Wilcox	Eagle Mills
46	Nevada	35	14 S	23 W	6,191	Wilcox	Smackover lime
47	Nevada	33	12 S	20 W	4,333	Wilcox	Smackover lime
48	Ouachita	31	13 S	16 W	4,076	Alluvium	Smackover
49	Ouachita	6	14 S	17 W	4,215	Claiborne	Smackover lime
50	Ouachita	22	15 S	17 W	5,680	Claiborne	Buckner
51	Ouachita	11	12 S	18 W	3,204	Wilcox	Smackover lime
52	Ouachita	35	13 S	18 W	4,210	Claiborne	Smackover lime
53	Ouachita	31	14 S	18 W	4,506	Claiborne	Cotton Valley
54	Ouachita	19	13 S	16 W	3,491	Claiborne	Smackover lime
55	Ouachita	16	14 S	18 W	4,573	Claiborne	Smackover lime
56	Ouachita	6	15 S	19 W	6,014	Claiborne	Smackover lime
57	Union	23	18 S	12 W	6,275	Claiborne	Smackover lime
58	Union	14	17 S	13 W	5,900	Claiborne	Smackover lime
59	Union	27	18 S	13 W	5,037	Claiborne	Cotton Valley
60	Union	9	17 S	13 W	5,835	Claiborne	Smackover lime
61	Union	31	17 S	14 W	6,710	Claiborne	Smackover lime
62	Union	12	19 S	15 W	7,910	Claiborne	Smackover lime
63	Union	15	17 S	18 W	7,260	Claiborne	Smackover lime

TABLE 3.—(*Continued*)

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks[1]
		Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Union Prod. Co.						Junked and abandoned
2	Placid Oil Co.						D. and A.
3	Placid Oil Co.						D. and A.
4	Placid Oil Co.						D. and A.
5	Placid Oil Co.						D. and A.
6	Placid Oil Co.						D. and A.
7	Placid Oil Co.						D. and A.
8	Placid Oil Co.						D. and A.
9	Placid Oil Co.						D. and A.
10	Placid Oil Co.						D. and A.
11	Placid Oil Co.	34		Pumping			Producing from Ozan, Hampton field
12	Placid Oil Co.						D. and A.
13	Placid Oil Co.						D. and A.
14	Skelly Oil Co.						D. and A.
15	Placid Oil Co.						D. and A.
16	Placid Oil Co.						D. and A.
17	Placid Oil Co.						D. and A.
18	Lion Oil Co.						D. and A.
19	Lion Oil Co.						D. and A.
20	H. L. Hunt						D. and A.
21	Lion Oil Co.						D. and A.
22	Lion Oil Co.						D. and A.
23	Talco Asphalt Co.						D. and A.
24	Tide Water Assoc.	387	0.194	1/4	600	Dual comp.	West Atlanta S.S. field
25	H. A. Wright & Phillips Petr. Co.	297	134	1/8	Packer	500	Mt. Holly extension
26	Tide Water Assoc.	694	0.900	1/4	Dual comp.	1,500	West Atlanta lime field
27	Roy Lee, Trustee	50	0.600	10/64	1,800	1,900	Columbia field
28	J. R. Hayden, Trustee						D. and A.
29	Hunt Oil Co.						D. and A.
30	Lion Oil Co.						D. and A.
31	Hunt Oil Co.						D. and A.
32	Northern Ordnance Inc.						D. and A.
33	Southwood Oil Co.						D. and A.
34	Hunt Oil Co.						D. and A.
35	Barnsdall Oil Co.						D. and A.
36	N. H. Wheless						D. and A.
37	W. G. Ray Drill. Co.						D. and A.
38	Magnolia Petr. Co.						D. and A.
39	Barnsdall Oil Co.						D. and A.
40	N. H. Wheless	138	1.5	11/64	1,880	1,740	Production Rodessa Wisinger field
41	Northern Ordnance Inc.						D. and A.
42	Sohio Prod. Co.						D. and A.
43	Plymouth Oil Co.						D. and A.
44	Plymouth Oil Co.						D. and A.
45	Placid Oil Co.						D. and A.
46	Hunt Oil Co.						D. and A.
47	Hunt Oil Co.						D. and A.
48	De Kalb Agri. Assn. Inc.						D. and A.
49	Jack Carnes						D. and A.
50	Robert A. Stacy						D. and A.
51	Jack Carnes						D. and A.
52	Jack Carnes						D. and A.
53	De Kalb Agri. Assn. Inc.						D. and A.
54	Danciger Oil & Ref. Co.						D. and A.
55	McAlester Fuel Co.						D. and A.
56	J. R. Hayden, Trustee						D. and A.
57	Lion Oil Co.						D. and A.
58	Lion Oil Co.						D. and A.
59	Phillips Petr. Co.						D. and A.
60	Phillips Petr. Co.	237		Pumping			Wilmington field
61	Fohs Oil Co.	103	0.154	3/16		360	Nick Springs C. V.
62	Carter Oil Co.						D. and A.
63	Atlantic Ref. Co.	168	0.045	3/16	325	Dual comp.	Mt. Holly C. V.

[1] D. and A., dry and abandoned.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1943	43	20
Number of oil wells completed during 1943	133	4
Number of gas wells completed during 1943		
Number of dry holes completed during 1943	51	62

Developments in the California Oil Industry during the Year 1943

By V. H. Wilhelm,[*] Member, and Max C. Eastman,[†] Junior Member A.I.M.E.

California had a record year in production and drilling activity, but the results have not been sufficient to keep up with the enormous increase in demand due to war activity.

During the year, 164 dry wildcats were drilled, 80 dry wells in proved areas, 31 gas wells, and 1158 successful oil-well completions for a total of 1433 wells, compared with a total of 765 in 1942.

With new discoveries of only 20,000,000 and production of 283,000,000 bbl. for the year, total reserves of California oil have decreased more than 250,000,000 bbl. However, revised estimates of the reserves of old fields indicate an increase in the state's reserves of 100,000,000 barrels.

The completion of 1158 wells has served only to maintain the maximum efficient daily rate of production at 800,000 barrels.

There is evidence in many fields that oil is being withdrawn too rapidly to obtain the maximum recovery, and more rapidly than is conducive to good production practice.

Statistics for 1943 as compared with 1942 are shown in the table in the next column.

Supply and Demand

Steadily mounting needs of the military forces and increased industrial consumption raised total demand for all petroleum products on the Pacific Coast to 914,000 bbl. daily in 1943. That all-time record demand was 149,000 bbl. daily higher than in 1942 and 214,000 bbl. daily above 1941 demand. Despite restrictions due to shortages of critical material, crude-oil production was boosted from 680,000 bbl. daily in 1942 to 779,000 bbl. daily in 1943, the highest level in 15 years. However, the new crude supply plus natural gasoline production and imports from other states totaled only 840,000 bbl. daily, leaving a deficiency between supply and demand of 74,000 bbl. daily.

Comparison of Statistics

Year	1942	1943
Number of new productive wells	578	1,158
Average initial potential of new well, bbl.	296	205
Crude production, avg. bbl. per day	680,000	778,597
Crude allotment, avg. bbl. per day	680,100	783,563
Demand in terms of crude, avg. bbl. per day	711,000	853,600
Discoveries for entire year, bbl.	25,000,000	20,000,000

That shortage had to be made up by withdrawals from inventories, which had been steadily depleted during the previous four years. Aboveground reserves, which totaled 159,574,000 bbl. on Jan. 1, 1939, were down to 98,000,000 bbl. at the end of 1943. Significantly enough, the greater part of that decrease occurred during the last six months of 1943, when more than 23,000,000 bbl. was taken from inventories of both crude and products. Although the size of total inventories on Dec. 31, 1943 might appear substantial, about 65 per

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cent was made up of crude petroleum and heavy residuum. Considering further that a large portion of the remaining refined products in storage are needed to carry on operations, it is evident that the inventory situation was distressingly critical at the beginning of the year.

Shortly before the close of 1943, the gasoline situation had deteriorated to such a degree that refiners were allocating civilian supplies to distributors. Despite curtailment of civilian use, demand for gasoline was running close to 300,000 bbl. daily (including naphthas) in the last quarter of 1943. The average of 268,000 bbl. daily for the full year was 14 per cent higher than in 1942 and was 26 per cent above demand just prior to the war. Although more gasoline was produced in 1943 than ever before and some of it was put in storage during the first few months of the year, finished and unfinished stocks were 4,000,000 bbl. lower on Dec. 31, 1943 than at the start of the year. With a large portion of the remaining inventory consisting of aviation gasoline and unfinished distillate, needing further treating and processing, what might be called "civilian reserves" were practically exhausted. With no prospect of improvement in sight, owing to the tremendous military demand for both aviation and motor gasoline, the civilian consumer is faced with the necessity of voluntarily holding down consumption to a much lower figure than last year or accepting stricter rationing possibly on a "priority" basis.

Demand for residual fuel oils also was at an all-time high in 1943, as millions of barrels were delivered to the Navy for its Pacific operations. In addition, railroads and industrial equipment were operating under peak-load conditions, all contributing to a total heavy fuel demand of 450,000 bbl. daily, 28 per cent above 1942 and 72 per cent higher than the 1940 demand.

Although heavy fuel production also established a new record of 402,000 bbl. daily in 1943, it was 48,000 bbl. daily short of requirements, some of which were restricted. As with gasoline, the deficiency between fuel-oil supply and demand grew from 23,000 bbl. daily in the first five months of 1943 to 66,000 bbl. daily in the last seven months. Reserves built up during the period of excess supply in 1937, 1938 and 1939 were gone before the start of 1943, and last year's draft of 17,000,000 bbl. reduced fuel residuum stock to less than 27,000,000 bbl. on Dec. 31. With better than two thirds of that amount considered necessary for processing and operating reserves, and with demand considerably in excess of supply, available fuel reserves probably will be exhausted before the end of the second quarter of 1944. At that time fuel-oil consumption also will have to be reduced to a figure commensurate with production.

New Discoveries—Oil Fields

San Joaquin Valley District

The Pleasant Valley, or Guajarral Hills field, was the only oil field of importance discovered in the state during the year. The discovery well, Standard Oil Company's well 82-29 F, S. 29, T. 20 S., R. 16 E., one mile southeast of the Coalinga Nose field, flowed at the rate of 819 bbl. of 28.5° gravity oil from a depth of 9142 ft., from Eocene sands. The new field is a permeability trap, or shore line, bordering the southeast end of the Coalinga Nose field. Productive area is expected to be 600 acres.

On the Tejon Ranch, 6 miles east of the Wheeler Ridge field, Richfield Oil Corporation discovered an accumulation of heavy oil after drilling four dry holes. The discovery well, Tejon 5, had an initial production of 70 bbl. of 18.2° gravity oil. The well is producing from overlapped Chanac oil sand of Pliocene age.

TABLE 1.—*Oil and Gas Production in California*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
								Producible Wells at End of 1943	1943	
				To End of 1943	During 1943	To End of 1943	During 1943		Completed	Abandoned
	SAN JOAQUIN VALLEY									
1	Belridge, North, *Kern*	1912	1,930	47,802,432	2,128,863	333,802	10,491	129	2	1
2	Belridge, South, *Kern*	1911	3,970	26,411,918	2,374,783			530	179	1
3	Buena Vista, *Kern*	1909	22,000	292,721,662	5,278,270	Incl. in Midway-Maricopa		948	42	10
4	Canal, *Kern*	1937	940	9,103,358	1,446,115	8,972	444	38	0	0
5	Coalinga, East, *Fresno*	1900	6,400	233,708,997	7,069,040	39,001	14,416	698	81	8
6	Coalinga, West, *Fresno*	1900	11,370	150,621,142	2,216,024			767	45	7
7	Coalinga Nose, *Fresno*	1938	3,030	40,181,402	17,977,139			169	1	0
8	Coalinga, Northeast, *Fresno*	1939	1,225	12,073,717	4,085,423			60	1	0
9	Coffee Canyon, *Kern*	1928	520	10,917,063	675,660	[1]	[1]	65	0	Incl. in Rd. Mt.
10	Coles Levee, North, *Kern*	1938	2,700	13,791,540	4,790,479	34,801	922	83	4	0
11	Coles Levee, South, *Kern*	1938	3,200	6,363,586	1,108,550			53	0	0
12	Edison, *Kern*	1934	1,695	10,218,981	892,399	Incl. in Mountain View		126	7	2
13	Elk Hills, *Kern*	1919	10,000	167,473,581	5,373,276	82,427	784	285	20	1
14	Fruitvale, *Kern*	1928	2,050	29,163,052	2,542,880	[1]	[1]	188	7	1
15	Greeley, *Kern*	1936	2,200	13,812,714	4,827,187	23,084	4,314	84	6	1
16	Helm, *Kern*	1941	3,380	250,208	166,854	2,183	1,359	13	4	0
17	Jacalitos, *Kern*	1941	800	178,375	118,229	[1]	[1]	7	1	0
18	Kern Front, *Kern*	1925	3,975	52,634,151	2,663,487	[1]	[1]	536	66	0
19	Kern River, *Kern*	1899	6,700	283,449,231	3,094,996	[1]	[1]	2,334	3	0
20	Kettleman North, *Kern*, *Fresno*	1928	16,720	280,505,767	15,289,757	1,659,568	80,004	348	8	3
21	Lost Hills, *Kern*	1910	2,560	54,015,359	1,322,301	[1]	[1]	407	10	1
22	McClung, *Kern*	1943	80	18,729	18,729	24	24	2	2	0
23	McKittrick District, *Kern*	1887	1,525	95,864,658	1,711,926	[1]	[1]	357	23	7
24	Midway-Maricopa, *Kern*	1901	33,000	660,321,448	14,928,802	397,290	9,304	2,890	115	9
25	Mountain View, *Kern*	1933	2,430	43,535,039	1,390,218	51,004	798	173	0	4
26	Mt. Poso District, *Kern*	1926	2,800	70,171,529	8,349,902	[1]	[1]	467	46	2
27	Paloma, *Kern*	1939	2,200	778,707	297,247	2,623	703	10	1	0
28	Pleasant Valley, *Fresno*	1943	500	234,813	234,813	187	187	6	6	0
29	Poso Creek District, *Kern*	1929	1,370	5,980,160	1,501,732	[1]	[1]	165	62	0
30	Raisin City, *Fresno*	1941	1,000	749,333	381,188	2,966	418	15	5	2
31	Rio Bravo, *Kern*	1937	2,140	21,761,379	5,443,121	23,665	6,242	101	1	0
32	Riverdale, *Fresno*	1941	2,500	699,025	601,274	1,095	731	32	19	0
33	Round Mountain, *Kern*	1927	1,500	27,830,945	3,447,544	[1]	[1]	224	32	0
34	Strand, *Kern*	1939	380	2,312,116	683,879	1,572	485	18	3	0
35	Ten Section, *Kern*	1936	2,260	26,947,986	6,557,724	48,103	17,070	123	0	0
36	Tejon, *Kern*	1943	80	3,552	3,552	[1]	[1]	1	2	0
37	Union Avenue, *Kern*	1941	200	156,959	40,916	460	10	5	0	0
38	Wasco, *Kern*	1938	360	2,948,985	779,486	*x*	275	13	0	0
39	Wheeler Ridge, *Kern*	1922	300	4,113,442	94,118	*x*	72	34	0	0
40	Williams (Antelope Plains), *Kern*	1942	260	842,193	751,094	478	478	20	11	0
41	Others			1,059,509	79,718	*x*	0	62	3	3
42	San Joaquin Valley total			2,701,728,743	132,738,695	*x*	149,531	12,586	817	63

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[b] Footnotes to column heads and explanation of symbols are given on page 270.

[1] Production of gas is small and not disposed of commercially.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil		Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift														
									SAN JOAQUIN VALLEY							
1	40	7	11	2,300 3,750	1,500 1,400	G	34.5	0.25	Etch.-Temb.-Vaq., Pli, Mio	S	14	4,917	625	A	Cretaceous	10,800
2	2	461	3				24	0.83	Etch.-Temb., Pli, Mio	S	*x*	800	50	A	Miocene	11,377
3		808				G	26.6	0.59	San Joaquin, Clay-Etch., Pli	S	25	2,665	50	A	Miocene	14,622
4	26	8	1	3,550	1,550		37.5	0.70	Stevens, Mio	S	22	8,250	160	A	Miocene	13,400
5		589					21.0	0.67	Etch.-Temb., Pli, Mio	S	25	1,860	170	AUP	Cretaceous	9,418
6		696					15.8	0.45	Etch.,Pli; Sta. Marg., Mio	S	*x*	900	180	MUP	Cretaceous	4,883
7	152	4	3	3,450	2,850		33	0.40	Avenal, Eoc	S	19	6,400	360	MU	Eocene	8,416
8	49	3		3,740	2,800		28	0.24	Avenal, Eoc	S	23	7,980	130	MU	Cretaceous	9,614
9		63					16	0.60	Vedder, Mio	S	*x*	1,600	60	MU	Incl. with Rd. Mt.	
10	68	1	1	3,700	3,200	P	36	0.40	Stevens, Mio	S	20	8,000	320	MC	Miocene	10,120
11	25			4,300	3,500	P	44	*x*	Stevens, Mio	S	20	8,300	200	MC	Miocene	10,101
12		115					18.5	0.75	Kern River-Temb., Pli, Mio	S	*x*	1,500	125	MU	L. Miocene	6,764
13	2	228					22.1	0.57	San Joaquin Clay-Etch.-Stevens, Pli, Mio	S	38	2,600	75	A	Miocene	11,177
14	6	161					19.8	0.60	Etch.-Chanac, Pli	S	*x*	3,000	88	MU	Jur.-Schist	10,590
15	70	10	3	3,200 4,890	1,600 3,500		38.5	0.28	Stevens-Vedder, Mio	S	21	11,430	290	AM	L. Miocene	12,504
16	10						65	0.02	Temblor-Eoc., Mio, Eoc	S	30	7,300	50	A	Cretaceous	10,257
17	1	6					40	0.48	Temblor, Mio, Eoc	S	*x*	3,865	11	AF	Cretaceous	6,031
18		510					14.4	1.29	Etchegoin, Pli	S	35	1,700	80	MF	Jur. slate	6,211
19		2,072					13.3	1.07	Kern River, Pli	S	35	400	130	MU	Oligocene	4,852
20	109	67	93	3,200 4,500	1,800 3,600	P	36.5	0.30	Temblor-Avenal, Mio, Eoc	S	15	6,300 10,200	850	A	Cretaceous	12,884
21		372					18	0.99	Etchegoin, Pli	S	*x*	1,170	80	A	Miocene	7,858
22		2					29	*x*	Stevens, Mio	S	22	7,482	15	A	Eocene	13,131
23		293					14.2	1.02	Etchegoin, Pli	S	*x*	800	350	MUF	Miocene	6,664
24		2,613					17.5	0.75	Etch.-Maricopa, Pli, Mio	S	30	1,950	65	MUF	Miocene	10,410
25		149					26	0.66	Chanac-Sta. Marg., Pli, Mio	S	*x*	6,080	55	MF	Granite	8,624
26		455					15.4	0.71	Vedder, Mio	S	35	1,600	150	MF	Granite	3,130
27	3			4,750	4,200	P	21	0.20	Stevens, Mio	S	20	10,140	200	A	Miocene	11,811
28	5	1					29.5	*x*	Avenal, Eoc	S	14	8,940	200	A	Eocene	9,151
29		159					13.7	*x*	Vedder, Mio	S	*x*	2,000	35	MU	Incl. with Rd. Mt.	
30		8	4				30	0.16	Temblor-Eoc., Mio, Eoc	S	21	5,040	10	A	Cretaceous Eocene	9,562
31	97			4,750	3,500		38.5	0.32	Vedder, Mio	S	22	11,249	220	A	Jur.-schist	14,108
32	28						35	*x*	Miocene-Eocene	S	*x*	6,500	35	AU	Jur.-slate	11,990
33		218					16.5	0.60	Jewett-Vedder, Mio	S	34	1,950	66	MF	Oligocene	6,070
34	16	2		3,600			35	0.37	Stevens, Mio	S	23	8,320	115	D	Miocene	12,818
35	110	4		3,550	2,900	P	35.4	0.34	Stevens, Mio	S	20	7,850	200	A	Miocene	10,023
36		1					18.3	*x*	Chanac, Pli	S	*x*	2,620	40	MU	Miocene	4,542
37		5					14.0		Chanac, Pli	S	*x*	4,200 5,050	30		Oligocene	10,427
38	9	4		5,670	5,000		38	0.26	Vedder, Mio	S	15	13,100	25	A	Eocene	15,004
39		34					23.5		Etch.-Sta. Marg., Pli, Mio	S		2,000	40	A	Oligocene	11,204
40	4	14					16.6	0.77	Miocene, Mio	S	30	2,200	60	AU	Oligocene	3,584
41	2	11														
42	842	10,150	115													

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To end of 1943	During 1943	To end of 1943	During 1943	Producible Wells at End of 1943	1943	
									Completed	Abandoned
	COASTAL DISTRICT									
	Santa Barbara District									
43	Capitan, *Santa Barbara*	1929	296	7,669,100	1,178,449	4,340	500	57	0	1
44	Elwood, *Santa Barbara*	1928	480	70,981,286	1,689,567	66,485	1,668	80	0	2
45	Santa Barbara, *Santa Barbara*	1929	165	3,453,336	40,835	[1]	[1]	19	0	0
	Santa Maria District									
46	Casmalia, *Santa Barbara*	1904	1,010	14,810,977	146,291	[1]	[1]	26	3	[5]
47	Cat Canyon, *Santa Barbara*	1908	1,550	22,080,344	1,551,739	[1]	[1]	84	9	2
48	Gato Ridge, *Santa Barbara*	1931	440	8,094,985	1,300,933	[1]	[1]	26	5	0
49	Lompoc, *Santa Barbara*	1903	2,735	11,208,551	598,141	[1]	[1]	31	1	[5]
50	Orcutt, *Santa Barbara*	1903	4,220	100,098,028	1,472,024	[1]	[1]	236	1	[5]
51	Santa Maria Valley, *Santa Barbara*	1934	5,610	37,939,883	8,267,837	12,929	5,363	261	23	1
	Ventura District									
52	Padre Canyon, *Ventura*	1936	180	2,443,461	365,962	20,509	476	20	0	0
53	Rincon, *Ventura*	1927	425	16,302,517	1,212,387		1,349	80	4	0
54	San Miguelito, *Ventura*	1931	430	8,678,834	1,591,134	12,351	2,950	29	2	0
55	Ventura Avenue, *Ventura*	1916	2,060	267,989,587	15,489,320	883,552	38,297	496	24	1
	Santa Paula-Newhall District									
56	Bardsdale, *Ventura*	1894	320	3,531,465	61,922	[1]	[1]	38	2	[6]
57	Del Valle, *Los Angeles*	1940	500	2,165,291	928,136	5,911	2,530	28	7	0
58	Ex-Mission, *Ventura*	1875	130	22,175,005[2]	11,435	[1]	[1]	24	0	[6]
59	Holser Canyon, *Ventura*	1942	30	19,870	13,277	[1]	[1]	2	1	[6]
60	Hopper Canyon, *Ventura*	1887	153	6,370,984[3]	46,058	[1]	[1]	10	0	[6]
61	Newhall, *Los Angeles*	1875	110	5,886,723[4]	24,608	[1]	[1]	23	0	21
62	Newhall Potrero, *Los Angeles*	1937	550	5,579,746	1,963,127	3,950	2,732	42	9	0
63	Oak Canyon, *Los Angeles*	1941	240	490,123	289,065	*x*	279	9	1	0
64	Oxnard, *Ventura*	1937	490	649,340	170,118	[1]	[1]	3	0	[5]
65	Sespe Canyon, *Ventura*	1887	289	3,103,465	70,706	[1]	[1]	29	0	[6]
66	Shiells Canyon, *Ventura*	1911	510	11,175,866	308,866	Inc. in. So. Mt.	695	131	4	[6]
67	Simi-Conejo, *Ventura*	1912	635	2,381,672	27,626	[1]	[1]	110	0	[6]
68	Sisar-Silverthread, *Ventura*	1885	330		40,893	[1]	[1]	78	1	[6]
69	South Mountain, *Ventura*	1916	785	23,742,077	525,077	71,567	2,304	97	0	[6]
70	Temescal, *Ventura*	1924	120	2,506,997	291,465	[1]	[1]	20	3	[6]
71	Timber Canyon, *Ventura*	1885	110		7,653	[1]	[1]	9	0	[6]
72	Torrey Canyon, *Ventura*	1896	140		53,400	[1]	[1]	42	1	[6]
	Other Coastal Counties									
73	East Elberta Pool, *San Luis Obispo*	1943	20	3,077	3,077	[1]	[1]	1	1	0
74	Pismo, *San Luis Obispo*	1928	200	106,894	2,449	[1]	[1]	4	0	0
75	Sargent, *Santa Clara*	1886	60	331,341	8,003	[1]	[1]	8	0	0
76	Others			4,020,303	8,542	*x*	4,570	117	0	0
77	Coastal District, total			665,991,128	39,760,116	*x*	63,713	2,270	102	28

[2] Includes: Ventura-Ojai, Tip Top Fresno, Sisar-Silverthread, and Timber Canyon.

[3] Includes: Modelo, Tapo Eureka, and Torrey Canyon.

[4] Includes: Wiley-Towsley Canyon.

[5] Included in Cat Canyon.

[6] Included in Newhall.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
COASTAL DISTRICT																
43		52					28	0.45	Vaqueros-Sespe, Mio, Olig	S	*x*	1,150	135	AF	Sespe	4,071
44	1	58					33.7	0.30	Monterey-Vaq.-Sespe, Mio, Olig	S	25	2,800	330	AF	Eocene	7,151
45		17					17	0.60	Vaqueros, Mio	S	*x*	1,960	75	MF	Sespe	4,730
46		10					10.3	2.84	Sisquoc-Monterey, Mio	H	*x*	1,200	Fis	A	Miocene	3,900
47	12	33					13.5	4.13	Sisquoc, Mio	S, H	*x*	2,000	Fis	A	Cretaceous	7,199
48		24					13.9	5.42	Sisquoc-Monterey, Mio	H	*x*	1,800	Fis	AF	Vaq., Mio	6,510
49	1	29					20.5	3.4	Sisquoc-Monterey, Mio	S, H	*x*	2,200	Fis	A	Miocene	4,310
50		199					22.6	2.63	Sisquoc-Monterey, Mio	S, H	*x*	1,100	Fis	A	Sespe-Olig	5,915
51	58	195		1,750		G	15.9	4.64	Monterey, Mio	S, H	*x*	4,000	Fis	MU	Franciscan	8,133
52	4	16		2,400	800		29.1	0.80	Pico-Repetto, Pli	S	*x*	4,800	140	AF	Miocene	6,751
53	10	58	7				30	0.80	Pico-Repetto, Pli	S	*x*	2,500	140	A	Pliocene	10,515
54	25	1	1	2,720	1,800	G	30		Pico-Repetto, Pli	S	*x*	5,500	680	AF	Pliocene	10,030
55	195	151	94	2,750			30	0.73	Pico-Repetto, Pli	S	*x*	3,400	3,000	A	Pliocene	11,516
56		28			2,000		32.1	0.83	Sespe-Tejon, Olig, Eoc	S	*x*	500	*x*	A	Eocene	6,804
57	19	8		2,800			32	1.21	Modelo, Mio	S	28	6,037	107	A	Miocene	9,850
58		23					25.2	0.70	Repetto, Pli	S	*x*	500	*x*	MF	*x*	*x*
59		2					16.5		Modelo, Mio	S	*x*	5,200	*x*	A	*x*	*x*
60		23					29		Modelo, Mio	S	*x*	1,500	*x*	A	Miocene	2,200
61		25			2,300		20.0		Modelo, Mio	S	*x*	858	*x*	A	Eocene	4,300
62	36	2	1	3,200			33.3	0.54	Modelo, Mio	S	16	6,160	230	AF	Miocene	8,120
63	5	3					33	0.83	Modelo, Mio	S	22	2,365	80	A	Miocene	8,090
64		3					8		Modelo, Mio	S	*x*	2,100	200	MU	Miocene	4,285
65		22					26.0	0.50	Sespe, Olig	S	*x*	400	*x*	A, S	Oligocene	3,595
66		114					33.0	0.69	Sespe, Olig	S	*x*	2,100	640	A	Eocene	7,428
67		54					28.1	0.68	Meganos, Eoc	S	*x*	1,100	*x*	A	Eocene	3,934
68		70					18.5		Sespe, Olig	S	*x*	315	*x*	MF	Eocene	3,934
69		94					23.9	1.73	Sespe, Olig	S	*x*	2,200	956	A	Eocene	6,702
70		20					22		Modelo, Mio	S	*x*	2,000	*x*	A	Miocene	4,584
71		8					28.7		Repetto-Modelo, Pli, Mio	S	*x*	300	*x*	MF	Miocene	3,300
72		38					27.5		Vaqueros-Sespe, Mio, Olig	S	*x*	700	*x*	AF	Miocene	2,500
73		1					18		Monterey, Mio	S	*x*	3,000	50	*x*	Miocene	3,155
74		2					22		Monterey, Mio	H	*x*	2,000	900	S	Jur. schist	4,425
75		8					13	0.86	Monterey, Mio	S, H	*x*	900	600	AF	Franciscan	3,583
76		10														
77	366	1,401	103													

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943	To End of 1943	During 1943	Producible Wells at End of 1943	1943	
									Completed	Abandoned
	LOS ANGELES BASIN									
78	Alamitos, *Los Angeles*	1931	200	24,742,330	280,067	[1]	[1]	37	0	0
79	Aliso, *Los Angeles*	1938	950	3,179,066	755,428	x	650	23	3	0
80	Brea Olinda, *Orange*	1889	1,680	175,846,424	4,247,839	64,373	3,234	425	6	0
81	Buena Park, *Orange*	1942	100	86,899	48,238	[1]	[1]	1	0	1
82	Coyote, East, *Orange*	1911	1,160	47,687,826	2,054,516	61,470	5,868	144	12	1
83	Coyote, West, *Orange*	1909	985	133,650,673	4,420,685			172	4	0
84	Dominguez, *Los Angeles*	1923	1,200	147,297,850	9,123,363	242,953	15,305	310	3	4
85	El Segundo, *Los Angeles*	1935	930	10,923,294	362,796	7,787	154	38	0	1
86	Huntington Beach, *Orange*	1920	2,200	326,208,279	13,216,799	331,074	10,973	822	66	19
87	Inglewood, *Los Angeles*	1924	1,075	139,345,042	6,908,649	106,515	7,063	313	3	0
88	Kraemer, *Orange*	1920	200	1,589,371	36,025	Inc. in Richfield		10	0	0
89	Long Beach, *Los Angeles*	1921	1,600	688,194,067	11,552,171	891,812	9,952	1,260	1	63
90	Los Angeles dist., *Los Angeles*	1892	1,627	66,400,822	177,699	[1]	[1]	92	0	0
91	Montebello, *Los Angeles*	1917	1,750	135,138,023	3,964,060	110,880	4,452	382	19	30
92	Playa Del Rey, *Los Angeles*	1934	670	49,645,172	959,811	51,022	762	133	1	6
93	Potrero, *Los Angeles*	1928	220	4,929,700	335,412	x	595	24	0	0
94	Richfield, *Orange*	1919	1,370	97,331,499	2,517,285	89,578	2,179	306	4	2
95	Rosecrans-Athens, *Los Angeles*	1924	850	53,074,865	2,192,113	132,868	5,140	195	2	3
96	Santa Fe Springs, *Los Angeles*	1919	1,630	492,234,064	7,302,985	686,175	6,397	611	0	14
97	Seal Beach, *Los Angeles*	1926	310	70,975,907	2,585,656	106,388	2,290	105	1	2
98	Torrance-Hermosa, *Los Angeles*	1922	6,200	110,049,430	2,832,044	80,654	1,701	719	37	24
99	Turnbull Canyon, *Los Angeles*	1941	80	245,038	121,836	154	88	6	1	0
100	Whittier, *Los Angeles*	1898	600	19,172,564	376,197		484	177	0	0
101	Wilmington, *Los Angeles*	1935	4,400	207,828,688	34,360,008	171,885	32,339	1,191	70	1
102	Yorba Linda	1919	300	1,287,522	397,087		[1]	31	8	0
103	Others[1]			1,948,497	34,865	x	5,784	42	3	0
104	Los Angeles Basin, total			3,009,012,912	111,163,634	x	115,410	7,569	244	171
105	STATE TOTAL			6,376,732,783	283,662,445	x	328,654	22,425	1,163	262

TABLE I.—(*Continued*)

	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.			Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
Line Number	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943	Secondary Recovery[h]	Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth of Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
									LOS ANGELES BASIN							
78	1	33	1				26.8	1.07	Pico-Repetto-Puente, Pli, Mio	S	x	4,635	250	AF	Miocene	9,054
79	6	2	10	1,750	1,390		24	0.47	Pico-Repetto-Modelo, Pli, Mio	S	x	4,795	170	M	Miocene	9,291
80	5	358	4				22.5	0.97	Repetto-Puente, Pli, Mio	S	x	260	800	AF	Miocene	8,021
81	1						20.9	2.42	Repetto, Pli	S	x	8,900	55	AM	Miocene	10,044
82	1	138					25	1.46	Repetto-Puente, Pli, Mio	S	x	2,450	153	AF	Miocene	9,084
83	20	132					28.9	0.90	Repetto, Pli	S	22	2,800	473	D	Miocene	9,200
84	33	221	45	1,700 3,000	50 500		30.4	0.85	Repetto-Puente, Pli, Mio	S	28	3,800	1,460	AF	Miocene	12,720
85		34					21.8	2.98	Puente, Franciscan, Mio, Jur	S, Fis	x	6,890	50	AF	Franciscan schist	8,009
86	29	707	1	1,000 1,600			23.5	1.30	Repetto-Puente, Pli, Mio	S	28	1,900	1,200	MF	Miocene	9,054
87	30	261	1				22.0 32.0	2.51 0.93	Pico-Repetto-Puente-Monterey, Pli, Mio	S	x	1,073	975	AF	Miocene	10,598
88		10					23.0	x	Repetto-Puente, Pli, Mio	S	x	4,100	x	A	Incl. in Richfield	
89		1,184					25	1.25	Pico-Repetto-Puente, Pli, Mio	S	30	2,377	1,650	AF	Miocene	10,720
90		91					13.7	1.0	Repetto-Puente, Pli, Mio	S	x	475	9	AF	Miocene	5,074
91		325	22				25 30	0.80 0.40	Repetto-Puente, Pli, Mio	S	x	1,730	800	A	Miocene	9,334
92		119					21	2.7	Repetto-Puente-Franciscan, Pli, Mio, Jur	Fis	x	3,350	200	A	Franciscan schist	7,048
93	3	10	11				44.5	1.3	Pico-Repetto-Puente, Pli, Mio	S	29	3,640	350	AF	Franciscan schist	9,923
94		298				G	20.5	1.60	Puente, Pli	S	x	2,900	510	A	Olig.-Sespe	10,496
95	11	123	52				33	0.48	Repetto-Puente, Pli, Mio	S	22	4,035	1,050	AF	Miocene	10,389
96		549	12				32.5	0.40	Repetto-Puente, Pli, Mio	S	29	3,470	1,360	D	Miocene	11,314
97	5	79	13				25	0.70	Repetto-Puente, Pli, Mio	S	x	4,314	350	AF	Miocene	9,054
98		651					22.0	1.62	Puente, Mio	S	27	2,637	120	AF	Franciscan schist	6,957
99		6					27	0.56	Puente, Mio	S	27	3,300	191	AF	Miocene	5,309
100	1	159					19	0.77	Repetto-Puente, Pli, Mio	S	x	200	270	MUF	Miocene	5,040
101	321	843	1				18 25 30	1.9 1.2 x	Repetto-Puente, Pli, Mio	S	32	2,320	420	AF	Franciscan schist	6,814
102	1	25					22	x	Repetto-Puente, Pli, Mio	S	x	3,400	x		Miocene	5,771
103		34														
104	468	6,392	173													
105	1,676	17,943	391													

Midway between Helm and Riverdale, the General Petroleum Corporation discovered a new field by the completion of its "Burrel" 68-35 flowing 342 bbl. per day of 31.4° gravity oil from 12 ft. of Temblor sand of Miocene age.

During the year the Helm field, discovered and controlled by the Amerada Petroleum Corporation, was extended by the Superior Oil Co. This field now has a productive area of 3380 acres. The previous production from Temblor sands had failed to maintain sustained production because of the thinness of the sand and high gas-oil ratio.

The Seaboard Oil Co., in partnership with the Tide Water Associated Oil Co. and the Union Oil Co., extended the Raisin City field in Fresno County 1¼ miles to the northwest by the completion of well S.T.U. 53-14 for a 480-bbl. rate of 24° gravity oil from a depth of 6305 ft., from sands of Eocene age. Previous production in the field was from thin Miocene sands.

Later the Shell Oil Co. extended the productive area of the Raisin City field an additional mile to the west by the completion of San Joaquin 1-1 for 44 bbl. of 22.4° gravity oil and 1000 M cu. ft. of gas from a depth of 5020 ft. from thin Miocene sands. All of the fields discovered in the San Joaquin Valley north of Coalinga in recent years are producing from very

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	B.t.u. of Gas	Gas Production, Millions Cu. Ft.[e]		Number Gas Wells[f]		
					To End of 1943	During 1943	Completed to End of 1943	1943	
								Completed	Abandoned
	GAS FIELDS								
1	Bowerbank, *Kern*	1942	1,500	995	839	839	3	0	0
2	Buena Vista Hills, *Kern*	1909	2,000	980	115,919	477	41	1	0
3	Buena Vista Lake, *Kern*	1934	1,200	1,000	4,616	299	1	0	0
4	Buttonwillow, *Kern*	1926	1,700	985	25,653	1,429	30	0	0
5	Chowchilla, *Madera*	1935	300	950 450	1	0	2 1	0	0
6	Coles Levee, *Kern*	1941	600	1,020	6,383	3,583	5	0	0
7	Elk Hills, *Kern*	1919	5,000	980	76,784	170	10	0	0
8	El Segundo, *Los Angeles*	1942	160	993	2,034	914	4	3	0
9	Fairfields Knolls, *Yolo*	1937	120	945	403	80	2	0	0
10	Gill Ranch, *Madera*	1943	1,000	960	38	38	4	4	0
11	Goleta, *Santa Barbara*	1929	200	1,055	7,942	Injection −1,999	6	0	0
12	Lodi, *San Joaquin*	1943	1,000	770	54	54	5	5	0
13	Marysville Buttes, *Sutter*	1936	2,000	1,000	5,698	663	5	1	0
14	McDonald Island, *San Joaquin*	1936	1,900	980	56,888	10,128	6	0	0
15	Moffat, *Madera*	1943	600	960	0	0	1	1	0
16	Potero Hills, *Solano*	1942		x	20	0	1	1	0
17	Rio Vista, *Sacramento, Solano*	1936	26,000	1,040	242,021	129,350	63	10	0
18	Roberts Island, *San Joaquin*	1942	80	1,040	634	540	1	0	0
19	Santa Fe Springs, *Los Angeles*	1919	40	980	293	87	1	0	0
20	Semi Tropic, *Kern*	1932	3,825	980	7,209	1,030	22	0	1
21	Thornton, *Sacramento, San Joaquin*	1943	240	780	2	2	3	3	0
22	Tompkins Hill, *Humboldt*	1937	520	1,040	753	321	4	0	0
23	Tracy, *San Joaquin*	1935	620	900	10,730	1,095	6	0	0
24	Trico, *Kern*	1935	7,500	980	15,461	2,066	32	0	0
25	Vernalis, *Stanislaus, San Joaquin*	1941	600	900	1,900	1,158	2	0	0
26	Willows, *Glenn*	1938	200	990	0	0	2	0	0

thin sands, and because of their relatively small volumetric content do not add appreciably to the state's oil reserves.

The Pacific Western Oil Co. discovered a small field north of Kern Front and west of Mount Poso oil fields by the completion of Enos No. 6, pumping 26 bbl. of 12.2° gravity oil. Production is from the Chanac sand of Pliocene age and closure is either by overlap or faulting.

A small fault-line field was discovered 2 miles west of the Round Mountain field by the Bandini Oil Co. with the completion of "Signal Mills" No. 1, for 150 bbl. of 16° gravity oil from a depth of 2435 ft. Production is from the Vedder sand of Miocene age and the productive area is estimated at 80 acres.

In the McClung area, Kern County, another small discovery was made by the Continental Oil Co. with the completion of K.C.L.-G No. 1 at a depth of 7518 ft., with an initial production of 250 bbl. per day from sand of Miocene age.

The Republic area of the Midway field near Fellows was extended for 50 additional acres by the completion of Chanslor-Canfield Midway Oil Co. well No. 79-6, for 173 bbl. of 20.4° gravity oil from 3070 ft., from the Republic sand of Miocene age.

The Standard Oil Co. extended the Greeley field for ½ mile to the south by the

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[f]	Character[k]	Porosity, Per Cent[l]	Depth of Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
Gas Fields																
1			3	1,700	1,550				Etchegoin, Pli	S	30	4,300	20	A	Miocene	12,138
2			21	*x*	200				San Joaquin clays, Pli	S	*x*	1,700	50	A	Miocene	14,622
3			1	1,660	1,210				Etchegoin, Pli	S	*x*	4,117	20	AF	Miocene	11,186
4			16	1,000	550				Etchegoin, Pli	S	*x*	2,500	18	D	Pliocene	4,946
5			0	*x*	*x*				Miocene, Cretaceous	S	*x*	2,611 7,900	60 140	D	Cretaceous	8,377
6			5	2,100	2,000				Etchegoin, Pli	S	*x*	5,000	20	MU	Miocene	10,120
7			2	*x*	250 450				San Joaquin clays, Pli	S	38	1,800	75	A	Miocene	11,177
8			3	2,000	*x*				Pliocene	S	*x*	2,193	20	D	Franciscan schist	8,009
9			2	1,475	1,425				Cretaceous	S	*x*	3,651	30	A	Cretaceous	5,185
10			4	1,975	1,960				Eocene	S	30	4,460	29	AF	Cretaceous	9,154
11			5	1,800	*x*				Vaqueros, Mio	S	*x*	4,139	354	AF	Eocene	6,912
12			5	975	975				Ione, Eoc	S	*x*	2,150	15	A	Schist	5,765
13			4	2,950	2,650				Cretaceous	S	28	2,700	87	MU	Igneous rock	6,900
14			4	2,350	2,000				Capay, Eoc	S	30	5,178	29	D	Cretaceous	8,810
15			1	1,760	1,760				Eocene	S	30	3,895	40	A	Eocene	4,308
16			0	1,315	1,000				Cretaceous	S		3,123	5	A	Cretaceous	4,400
17			63	1,860	1,550				Domingine-Ione, Eoc	S	35	3,800	148	AF	Cretaceous	7,029
18			1	2,063	2,050				Capay, Eoc	S	*x*	5,240	10	A	Eocene	5,262
19			1	*x*	500				Repetto, Pli	S	*x*	2,500	20	D	Miocene	11,314
20			15	1,110	800				Etchegoin, Pli	S	25	2,275	6	A	Miocene	9,700
21			0	1,500	1,500				Ione, Eoc	S	*x*	3,350	5	A	Cretaceous	8,367
22			4	2,488	*x*				Repetto, Pli	S, H	26	3,800	170	A	Pliocene	7,708
23			4	1,750	925				Cretaceous	S	28	3,926	65	D	Cretaceous	9,690
24			26	1,157	950				Etchegoin, Pli	S	28	2,420	13	A	Miocene	11,468
25			2	1,620	1,360				Cretaceous	S	*x*	3,840	30	A	Cretaceous	3,873
26			0	675	675				Cretaceous	S	*x*	2,345	10	D	Cretaceous	6,014

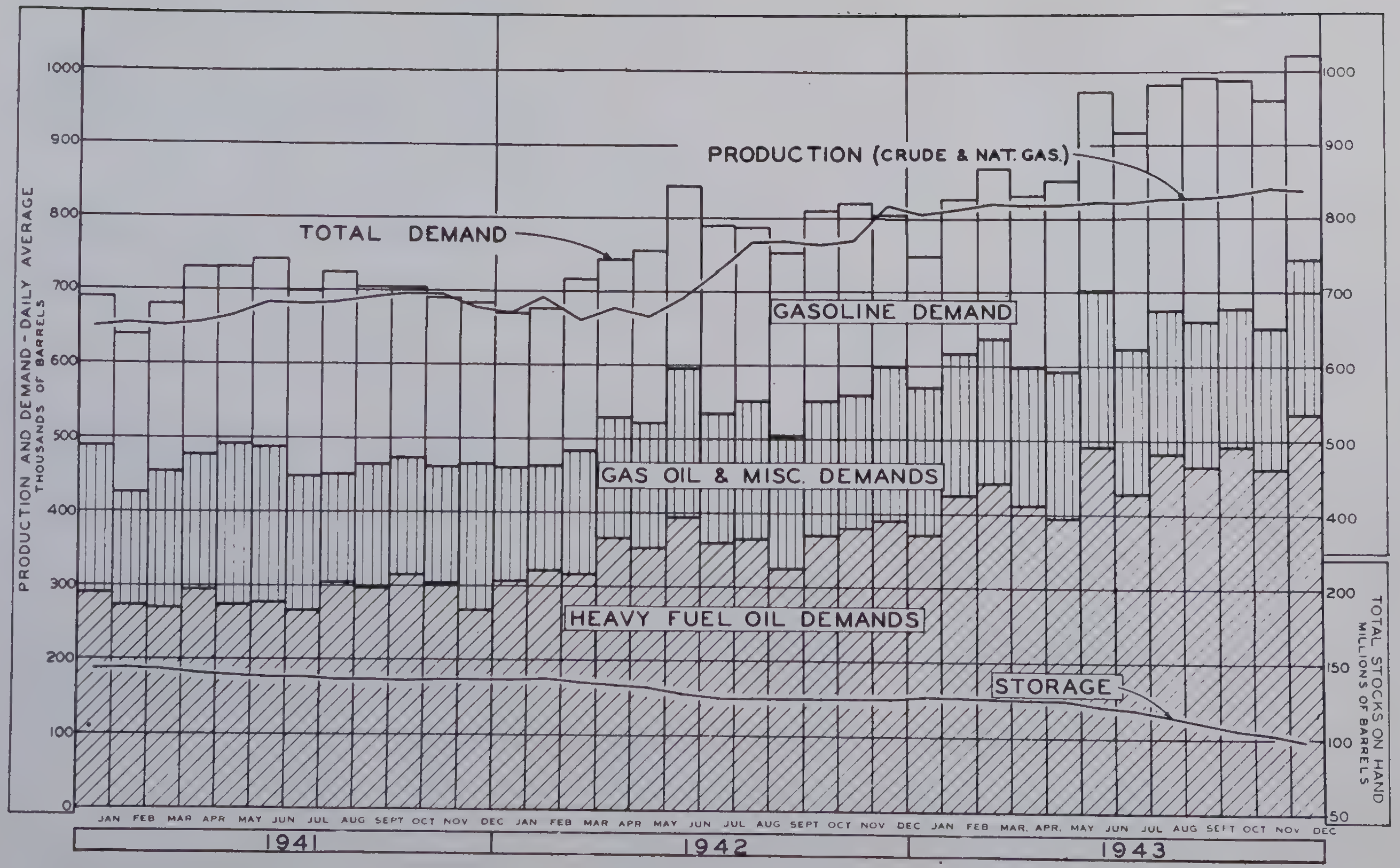

FIG. 1.—PRODUCTION AND DEMAND IN CALIFORNIA.

completion of its Wegis Community No. 1, for 300 bbl. of 35° gravity oil from a depth of 11,600 ft. from the Vedder sand of Miocene age. Future drilling may prove this well to be on a separate structure.

Coastal and Los Angeles Basin Districts

No new fields were discovered in the Coastal and Los Angeles Basin districts. There were added, however, several new pools and extensions of old ones.

Two new pools were discovered in the Del Valle field in Los Angeles County. East of Del Valle, R. E. Havenstrite, in his Barnes No. 2, discovered the Bering pool at a depth of 9629 ft. Formation is of Miocene age. Initial production was 1600 bbl. per day of 43° gravity clean oil. West of Del Valle, Bankline Oil Co., in its Sterry No. 101, discovered the Sterry pool at a depth of 4500 ft. Formation is of Miocene age. Initial production was 100 bbl. per day of 23° gravity oil with some water.

A new zone was discovered in the Pismo field, San Luis Obispo County, by the Los Nietos Co. in its Scott No. 1 well. This is a small well producing from sand of Miocene age at a depth of 3155 feet.

Standard Oil Co. extended the Cat Canyon field in Santa Barbara County by the completion of its South Basin-Lloyd Community No. 1 at a depth of 4705 ft. in sand of Miocene age. This is a 100-bbl. per day pumper of low-gravity oil.

Los Nietos Co. extended the Bardsdale field by the completion of its Elkins No. 1 well at a depth of 4919 ft. in sand of Miocene age. Initial production was 125 bbl. per day of 29° gravity oil.

The intensive wildcatting activity of the year, 185 wells, fell far short of the discoveries and additions hoped for, but it did develop six small fields and seven extensions of old fields. However, in the main, all the discoveries of the year are small and additions to reserves from new fields will not be over 20,000,000 barrels.

NEW DISCOVERIES—GAS FIELDS

The year 1943 was remarkable for the number of gas fields discovered. All of these fields are in northern California, and were the result of geophysical exploration.

Near Lodi, Sacramento County, three gas fields were discovered, two of which are very small in area and produce gas of doubtful value because of the presence of from 21 to 34 per cent nitrogen. The important discovery was made by the Amerada Petroleum Corporation with the completion of its Capital Company No. 1, producing 6800 M cu. ft. from a depth of 3390 ft. Production is from Eocene sands, with an average thickness of 30 ft. Subsequent development indicates that the total productive area is not more than 500 acres. The gas is marketable, having a heating value of 972 B.t.u. with 7.2 per cent nitrogen.

Six miles north of Lodi and 6 miles west of the Amerada discovery, Bankline Oil Co. discovered a one-well field by the completion of its Community 1-1 for 8000 M cu. ft. from the Capay sands of Eocene age at a depth of 2340 ft. The gas has a 34 per cent nitrogen content with a B.t.u. value of 680.

Three miles northwest of the Bankline discovery, Amerada discovered a small field by the completion of its Lodi Community 9-1, producing 7200 M cu. ft. from a depth of 2270 ft. in the Eocene sand. The gas contains 21 per cent nitrogen with a B.t.u. value of 750.

Near Mendota The Texas Company discovered the Gill Ranch gas field, with the completion of its Gill 14-16, for 4900 M cu. ft. from a depth of 4500 ft. from Domingine sands of Eocene age. The gas is 97 per cent methane with a B.t.u. value of 1000. Net sand thickness is 29 ft. and the estimated ultimate productive area is 2000 acres.

Five miles northwest of the Gill field, The Texas Company discovered the

Moffat field with the completion of its Moffat 1-7 for 7000 M cu. ft. from a depth of 4308 ft. Production is from the Eocene sands, with an estimated productive area of 600 acres.

The most important addition to gas reserves of the year was the discovery of deeper gas sands in the large Rio Vista gas field. Standard-Texas Midland Fee No. 5 was brought in producing 20,000 M cu. ft. from 180 ft. of Eocene sand. Approximately 4000 acres of the 25,000-acre area of the field is underlain by this sand.

In Colusa County the General Petroleum Corporation discovered a new gas field by the completion of its Capital No. 1 for 4500 M cu. ft. from a depth of 2940 feet.

Refining

The refining industry perhaps has made more progress during the year than it had for the whole preceding decade. Twelve new 100-octane plants are or soon will be in operation in California. Six more are under construction. The new-type refineries permit an increased recovery of aviation gasoline of 700 per cent for each barrel of crude, with a resultant decrease of 30 per cent in automotive gasoline and a 10 per cent increase in fuel oil. The so-called 100-octane gasoline of 1943 is also far superior for aviation purposes to the prewar 100-octane gasoline. Although it is called gasoline, the new aviation fuel is not a gasoline but a new type of fuel produced by rearranging the molecules through the use of catalysts.

Although the actual figures are not for publication, it is estimated that at the end of the year more than 50 per cent of California's gasoline supply was being used by the armed forces, whereas the military was consuming 35 per cent of the nation's total supply.

Conclusion

Optimistic estimates indicate that 1500 producing wells will be completed in California in 1944. Naturally, this figure is dependent on the availability of proved locations, which are becoming increasingly rare. The new locations are expected to be mainly in the Jones sand of the Huntington Beach offshore field; the Ford and Tar zones in the Wilmington field; and in the many zones of the Ventura Avenue field, which has 3000 ft. of net sand distributed through 7000 ft. of formation.

The demand for California oil is expected to increase beyond the record 1943 figure. Consistent withdrawals from storage in 1943 and so far in 1944 have reduced stocks of certain products, notably gasoline and heavy fuel, to a critical level. Plans are being made to supply part of the Pacific-area demand from sources other than California. If this is not done, the existing shortage of petroleum products on the Pacific Coast will become more acute as the year progresses.

With the experience of 1943, when the completion of 1158 wells did not increase the maximum efficient rate of production, it cannot be anticipated that drilling during 1944 will increase the present maximum efficient rate of 800,000 bbl. per day. Completion of these wells will only serve to offset the natural decline, which is at least 15 per cent per year.

The lack of labor and shortage of equipment have been major problems in production and drilling. Already women have invaded the domain of the pumper and have proved remarkably efficient. Supplies are still difficult to obtain, but this shortage is rapidly being overcome.

Oil and Gas Development in Illinois in 1943

By Alfred H. Bell,* Member A.I.M.E., and Charles W. Carter*

In 1943, Illinois produced 82,256,000 bbl. of oil, or 5.5 per cent of the total for the United States, and ranked sixth in the nation in oil production. This represents a decline of 23 per cent from 1942, when the total Illinois production was 106,500,000 bbl. and Illinois ranked fifth. The daily average production for 1943 was approximately 225,000 bbl. Daily averages by months were as follows:

Jan.	238,000	July	218,000
Feb.	240,000	Aug.	216,000
Mar.	237,000	Sept.	220,000
Apr.	230,000	Oct.	220,000
May	221,000	Nov.	223,000
June	222,000	Dec.	218,000

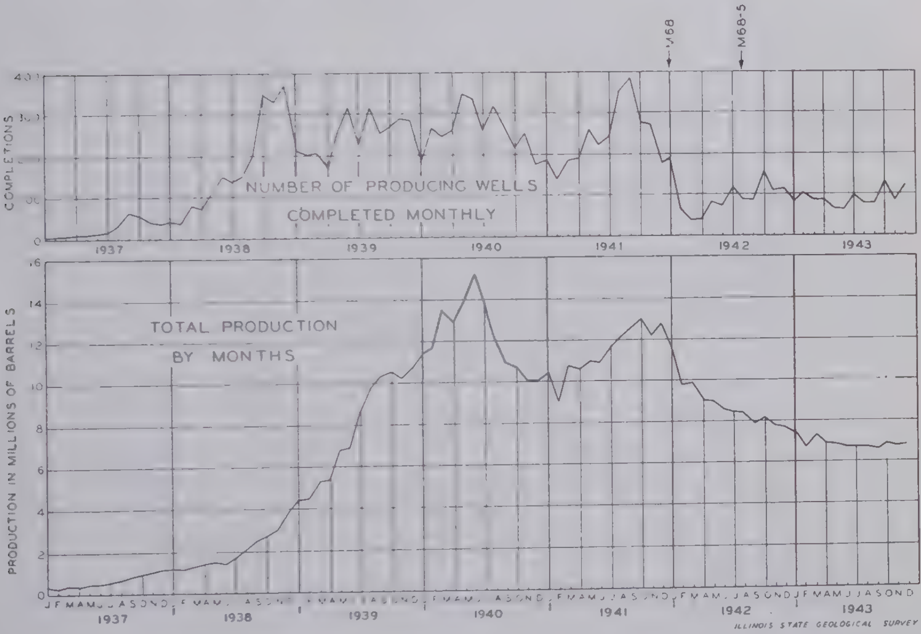

Fig. 1.—Number of producing wells completed monthly and oil production by months in Illinois, 1937–1943.

Dates of issue of Federal Conservation Order M-68 and M-68-5, regulating well spacing to save steel, are shown.

This shows that most of the decline during the year took place between March and May, and that for the last eight months of 1943 production has been essentially steady. This means that there has been enough production from new wells drilled to balance the natural decline of the older wells. The trends of drilling and production are shown in Fig. 1 and Table 3.

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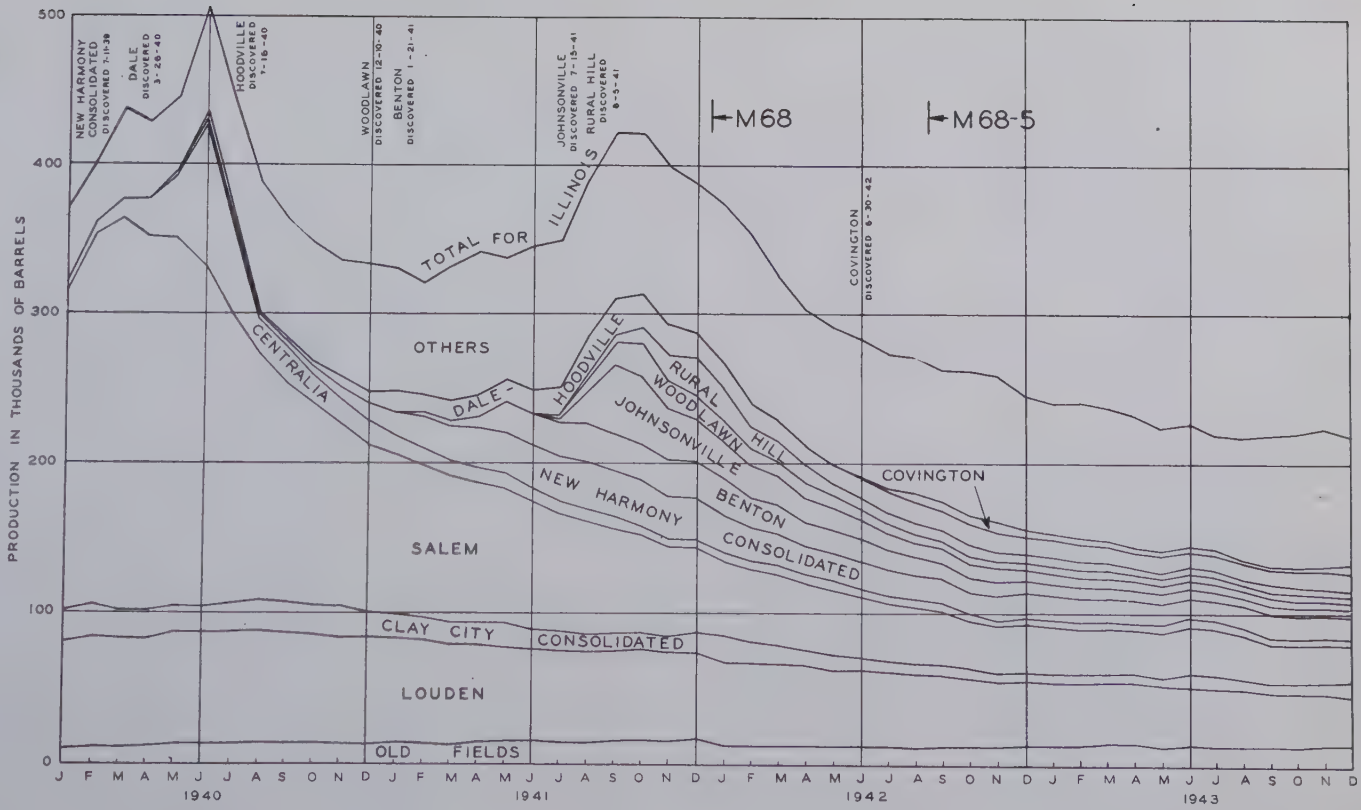

ILLINOIS STATE GEOLOGICAL SURVEY

FIG. 2.—TOTAL DAILY OIL PRODUCTION BY MONTHS FOR ILLINOIS, SHOWING AMOUNTS CONTRIBUTED BY MAJOR FIELDS, 1940–1943. Dates of issue of Federal Conservation Order M-68 and M-68-5, regulating well spacing to save steel, are shown.

During the past year, 1791 wells were drilled for oil and gas in Illinois as compared with 2016 in 1942, a reduction of 11 per cent. Of the former number, 461 are classified as "wildcat" as compared with 549 in 1942. Twenty-eight new pools were discovered in 1943 as compared with 40 in 1942. No major pools have been discovered in Illinois since 1942. A graph of the productions of major fields in relation to the state total for the years 1940–1943 is shown in Fig. 2.

Prices of crude oil and federal regulations of well spacing in Illinois have remained unchanged throughout 1943.

Data on production and drilling by fields are given in Table 1.

DISCOVERIES

Twenty-eight new fields (Fig. 3, Table 2*A*), 66 extensions (Table 2*B*), and 49 additional producing zones in existing fields (Table 2*C*) were discovered in 18 counties in Illinois during 1943. Of the 28 new fields, none were abandoned during the year, 10 were one-well fields, 13 had not more than 6 wells, two had 7 wells, one had 8, one had 10, and the largest new field, Calvin North in White County, was producing from 23 wells by the end of the year. In all, 110 wells were producing in these fields as of Jan. 4, 1944. In 1942, for comparison, 200 wells were producing from 37 new fields at the end of the year.

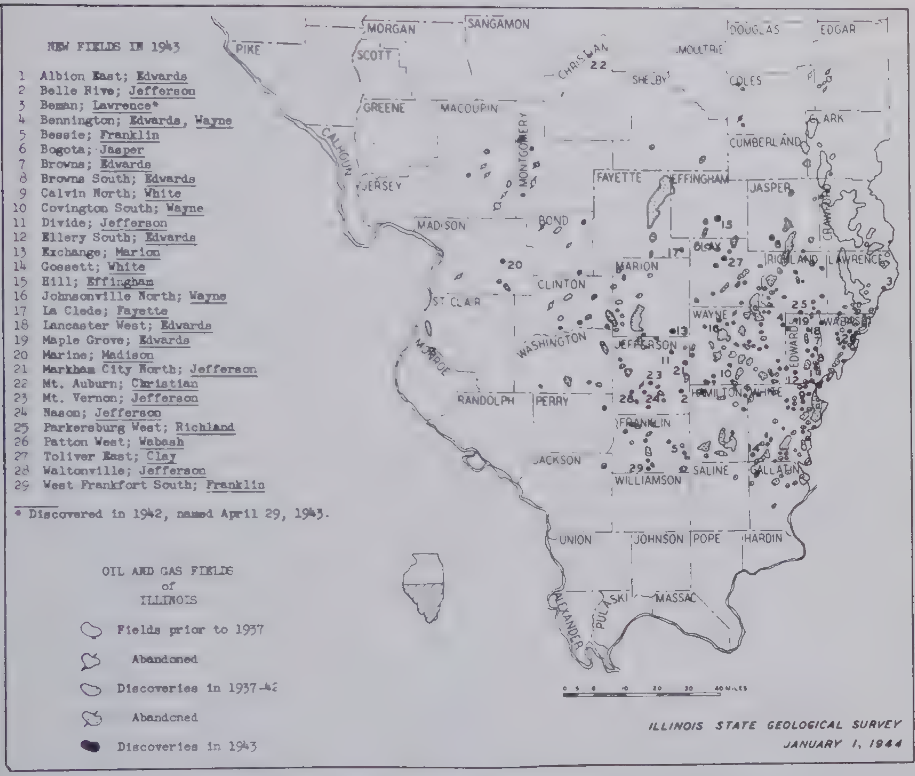

FIG. 3.—INDEX MAP OF NEW OIL FIELDS DISCOVERED IN ILLINOIS IN 1943.
Older fields are also shown, except those in Colmar-Plymouth, McDonough and Hancock Counties, which are outside of the area of the map.

TABLE 1.—*Oil and Gas Production in Illinois*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
1	Warrenton-Borton, *Edgar*	1906	100	30,000	0		0	0	22	0	0
2	Westfield, *Clark, Coles*	1904	9,075	*x*	*x*		*x*	0	1,628	0	0
3			925	*x*	*x*		*x*	0	186	0	0
4			9,000	*x*	*x*		*x*	0	1,449	0	0
5			220	*x*	*x*		*x*	0	13	0	0
6	Siggins, *Cumberland, Clark*	1906	3,685	*x*	*x*		*x*	0	996	0	2
7			3,190	*x*	*x*		*x*	0	854	0	0
8			450	*x*	*x*		*x*	0	90	0	0
9			960	*x*	*x*		*x*	0	193	0	0
10	York, *Cumberland, Clark*	*x*	350	*x*	*x*		*x*	0	70	0	0
11	Casey, *Clark*	1906	1,980	*x*	*x*		*x*	0	535	0	0
12			205	*x*	*x*		*x*	0	41	0	0
13			400	*x*	*x*		*x*	0	82	0	0
14			1,540	*x*	*x*		*x*	0	322	0	0
15	Martinsville, *Clark*	1922	865	*x*	*x*		*x*	0	219	1	0
16			35	*x*	*x*		*x*	0	7	0	0
17			310	*x*	*x*		*x*	0	64	1	0
18			710	*x*	*x*		*x*	0	23	0	0
19			600	*x*	*x*		*x*	0	35	0	0
20			640	*x*	*x*		*x*	0	40	0	0
21			10	*x*	*x*		*x*	0	2	0	0
22	North Johnson, *Clark*	1907	1,440	*x*	*x*		*x*	0	485	0	0
23			1,115	*x*	*x*		*x*	0	296	0	0
24			160	*x*	*x*		*x*	0	32	0	0
25			825	*x*	*x*		*x*	0	177	0	0
26			215	*x*	*x*		*x*	0	44	0	0
27	South Johnson, *Clark*	1907	1,780	*x*	*x*		*x*	*x*	536	1	8
28			190	*x*	*x*		*x*	*x*	38	0	0
29			295	*x*	*x*		*x*	*x*	59	0	0
30			1,710	*x*	*x*		*x*	*x*	403	1	4
31			850	*x*	*x*		*x*	*x*	170	0	4
32	Bellair, *Crawford, Jasper*	1907	1,305	*x*	*x*		*x*	*x*	486	0	4
33			1,165	*x*	*x*		*x*	*x*	310	0	2
34			315	*x*	*x*		*x*	*x*	65	0	2
35			910	*x*	*x*		*x*	*x*	182	0	0
36	Clark County Division[1]		20,480	53,856,000	365,000		*x*	*x*	4,955	2	14
37	Main,[2] *Crawford*	1906	35,650	*x*	*x*		*x*	*x*	7,324	0	198
38			340	*x*	*x*		*x*	*x*	68	0	0
39			34,305	*x*	*x*		*x*	*x*	7,143	0	175
40			1,000	*x*	*x*		*x*	*x*	108	0	23
41			10	*x*	*x*		*x*	*x*	1	0	0
42	New Hebron, *Crawford*	1909	1,560	*x*	*x*		*x*	*x*	297	0	0
43	Chapman, *Crawford*	1914	1,560	*x*	*x*		*x*	*x*	193	0	0
44	Parker, *Crawford*	1907	1,340	*x*	*x*		*x*	*x*	256	0	10
45	Allison-Weger, *Crawford*	*x*	1,095	*x*	*x*		*x*	*x*	148	0	0
46	Flat Rock,[3] *Crawford*	*x*	1,920	*x*	*x*		*x*	*x*	289	0	4
47	Birds, *Crawford, Lawrence*	*x*	4,485	*x*	*x*		*x*	*x*	684	0	42
48	Crawford County Division[4]		47,610	149,956,000	1,303,000		*x*	*x*	9,191	0	268
49	Lawrence, *Lawrence, Crawford*	1906	25,700	*x*	*x*		*x*	*x*	9,424	9	84
50			50	*x*	*x*		*x*	*x*	5	0	*x*
51			5,050	*x*	*x*		*x*	*x*	1,233	0	*x*
52			2,240	*x*	*x*		*x*	*x*	481	5	*x*
53			1,440	*x*	*x*		*x*	*x*	243	0	*x*
54			16,180	*x*	*x*		*x*	*x*	3,017	0	*x*
55			4,220	*x*	*x*		*x*	*x*	697	4	*x*
56			6,950	*x*	*x*		*x*	*x*	959	0	*x*
57	St. Francisville, *Lawrence*	*x*	420	*x*	*x*		*x*	*x*	55	0	0
58	Lawrence County Division[7]		26,120	231,249,000	1,726,000		*x*	*x*	4,479	9	84

[1] Total of lines 2, 6, 10, 11, 15, 22, 27, 32.

[2] Includes Kibbie, Oblong, Robinson, and Hardinsville.

[3] Includes Swearingen gas.

[4] Total of lines 37, 42, 43, 44, 45, 46, 47.

[7] Total of lines 49 and 57.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.[5]		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.[6]	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
1	0	2	0	x	x	W	x	x	Unnamed; Pen	S	P	159	x	ML	"Trenton"	2,212
2	0	291	0	293±	x		34.0	x						D	St. Peter	3,009
3	0	x	0	x	x		30.0	x	Shallow gas; Pen	S	P	281	36	D		
4	0	x	0	x	x		33.5	x	Westfield; MisL	L	Cav	334	x	D		
5	0	x	0	x	x		38.2	0.18	"Trenton"; Ord	L	P	2,265	x	D		
6	0	800	0	x	x	P	33.0	x						D	Dev	2,010
7	0	x	0	x	x		34.0	x	First Siggins; Pen	S	P	367	x	D		
8	0	x	0	x	x		(33.6)	x	2nd & 3rd Siggins; Pen	S	P	478	x	D		
9	0	x	0	x	x		(25.7)	x	Lower Siggins; Pen	S	P	556	x	D		
10	0	44	0	x	x		(30.3)	x	York; Pen	S	P	588	x	AM	Pen	960
11	0	488	0	x	x	P	29.2	x						AM	MisL	808
12	0	x	0	x	x		(31.9)	x	Upper gas; Pen	S	P	263	x	AM		
13	0	x	0	x	x		(30.1)	x	Lower gas; Pen	S	P	309	x	AM		
14	0	x	0	x	x		(33.6)	x	Casey; Pen	S	P	444	x	AM		
15	0	116	0	x	x		36.8	x						D	St. Peter	3,411
16	0	x	0	x	x		x	x	Shallow; Pen	S	P	255		D		
17	0	x	0	x	x		x	x	Casey; Pen	S	P	499	x	D		
18	0	x	0	x	x		x	x	Martinsville; MisL	L	P	477	x	D		
19	0	x	0	x	x		(38.9)	x	Carper; MisL	S	P	1,340	x	D		
20	0	x	0	x	x		x	x	"Niagaran"; Dev	L	P	1,553	x	D		
21	0	x	0	x	x		(39.6)	x	"Trenton"; Ord	L	P	2,708	x	D		
22	0	433	0	x	x		31.0							AM	Mis	965
23	0	x	0	x	x		x	x	Claypool; Pen	S	P	416	x	AM		
24	0	x	0	x	x		x	x	Shallow; Pen	S	P	314	x	AM		
25	0	x	0	x	x		x	x	Casey; Pen	S	P	465	x	AM		
26	0	x	0	x	x		x	x	Upper Partlow; Pen	S	P	534	x	AM		
27	0	462	0	x	x		32.2							AM	Dev	2,030
28	0	x	0	x	x		x	x	Claypool; Pen	S	P	392	x	AM		
29	0	x	0	x	x		x	x	Casey; Pen	S	P	453	x	AM		
30	0	x	0	x	x		x	x	Upper Partlow; Pen	S	P	489	x	AM		
31	0	x	0	x	x		28.5	x	Upper Partlow; Pen	S	P	598	x	AM		
32	0	371	0	x	x	P	33.7	x						AM	MisL	1,471
33	0	x	0	x	x		(32.4)	x	"500 ft."; Pen	S	P	561	x	AM		
34	0	x	0	x	x		x	x	"800 ft."; Pen	S	P	817	x	AM		
35	0	x	0	x	x		(37.0)	x	"900 ft."; MisU	S	P	886	x	AM		
36	0	3,005	0	x	x		33.0								St. Peter	4,654
37	0	4,623	x	425±	x	P	33.0	x								
38	0	x	x	x	x		x	x	Shallow; Pen	S	P	508	x	ML		
39	0	x	x	x	x		32.8	x	Robinson; Pen	S	P	900	25±	ML		
40	0	x	x	x	x		x	x	Oblong; Mis	SL	P	1,337	x	A, ML		
41	0	1	0	x	x		x	x	Devonian; Dev	L	P	2,794	11	ML		
42	0	146	0	x	x	P	30.1	x	Robinson; Pen	S	P	940	x	ML	Mis	2,056
43	0	60	0	x	x		x	x	Robinson; Pen	S	P	995	x	ML	Mis	2,279
44	0	209	0	x	x		29.5	x	Robinson; Pen	S	P	1,000	x	ML	Pen	1,127
45	0	66	0	x	x		22.5	x	Robinson; Pen	S	P	912	x	ML	Pen	1,041
46	0	126	0	x	x		31.8	x	Robinson (Flat Rock); Pen	S	P	935	x	ML	Dev	3,110
47	0	382	0	x	x		31.8	x	Robinson; Pen	S	P	930	x	ML	MisL	1,731
48	0	5,612	0	425±	x		32.3	x							St. Peter	4,654
49	0	3,080	0	650±	x		32.9	x						A	St. Peter	5,190
50	0	5	0	x	x		x	x	Pennsylvanian; Pen	S	P	290	x	A		
51	0	x	0	x	x		x	x	Bridgeport; Pen	S	P	800	40	A		
52	0	x	0	x	x		x	x	Buchanan; Pen	S	P	1,250	15	A		
53	0	x	0	x	x		x	x	"Gas"; MisU	S	P	1,330	15	A		
54	0	x	0	600±	x		x	x	Kirkwood; MisU	S	P	1,400	30	A		
55	0	x	0	650±	x		x	x	Tracey; MisU	S	P	1,560	20	A		
56	0	x	0	x	x		x	x	McClosky; MisL	L	P	1,700	10	A		
57	0	30	0	600	x		37.3	x	Bethel; MisU	S	P	1,843	22	ML	Mis	1,900
58	0	3,110	0	x	x										St. Peter	5,190

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[5] Pressures in Southeastern Illinois oil fields are estimated bottom-hole pressures reported in previous Survey publications.

[6] Gravities given prior to 1936 (except those in parentheses) were from data for the year 1925 furnished by the Ohio Pipe Line Company (formerly called the Illinois Pipe Line Company). Gravities in parentheses are for particular samples (see Ill. State Geol. Survey Bull. 54, Table 3). The values have been converted from Baumé to A. P. I. gravities.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c] To End of 1943	Oil Production Total, Bbl.[c] During 1943	Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e] To End of 1943	Gas Production, Millions Cu. Ft.[e] During 1943	Number of Oil and/or Gas Wells[f] Completed to End of 1943	Number of Oil and/or Gas Wells[f] 1943 Completed	Number of Oil and/or Gas Wells[f] 1943 Abandoned
59	Allendale, *Wabash*	1912	2,400	6,339,000	809,000		*x*	*x*	528	25	5
60			*x*	*x*	*x*		*x*	*x*	467	19	2
61			*x*	*x*	*x*		*x*	*x*	3	0	0
62			*x*	*x*	*x*		*x*	*x*	6	1	0
63			*x*	*x*	*x*		*x*	*x*	6	0	0
64			*x*	*x*	*x*		*x*	*x*	36	4	3
65			*x*	*x*	*x*		*x*	*x*	9	1	0
66	Total Southeastern Fields[8]		96,710	441,430,000	4,203,000		*x*	*x*	19,175	36	371
67	Ayers gas, *Bond*	1922	325	0	0		221.2	14.1	21	1	0
68	Greenville gas, *Bond*	1910[9]	160	0	0		990.0	0	4	0	0
69	Bartelso, *Clinton*	1936	580	1,356,000	154,000		0	0	73	1	1
70			320	861,000	79,000		0	0	48	1	1
71			230	495,000	75,000		0	0	25	0	0
72	Carlyle, *Clinton*	1911	915	3,481,000	30,000		0	0	165	0	36
73	Frogtown, *Clinton*	1918[10]	300	*x*	0		0	0	12	0	0
74	Ava-Campbell Hill, *Jackson*	1917[11]	440	*x*	0		*x*	0	35	0	0
75	Colmar-Plymouth, *McDonough, Hancock*	1914	2,450	2,991,000	97,000		0	0	486	0	0
76	Carlinville, *Macoupin*	1909[12]	80	*x*	500		*x*	0	8	0	0
77	Gillespie-Benld gas, *Macoupin*	1923[13]	80	0	0		135.8	0	4	0	0
78	Gillespie-Wyen, *Macoupin*	1915	40	*x*	1,000		0	0	22	0	0
79	Spanish Needle Creek, *Macoupin*	1915[14]	80	0	0		14.4	0	7	0	0
80	Staunton gas, *Macoupin*	1916[15]	400	0	0		1,050.0	0	18	0	0
81	Collinsville, *Madison*	1909[16]	40	850	0		0	0	6	0	0
82	Brown, Langewisch-Kuester, Junction City, *Marion*	1910	175	*x*	*x*		0	0	14	1	1
83			60	*x*	*x*		0	0	7	0	1
84			115	*x*	*x*		0	0	7	1	0
85	Sandoval, *Marion*	1909	770	5,038,000	144,000		0	0	150	0	1
86			770	2,700,000	5,000		0	0	123	0	1
87			380	2,338,000	139,000		0	0	27	0	0
88	Wamac, *Marion, Clinton, Washington*	1921	250	469,000	13,000		0	0	106	0	7
89	Litchfield, *Montgomery*	1879[17]	100	22,800	500		0	0	18	0	0
90	Waterloo, *Monroe*	1920[18]	230	224,000	4,000		0	0	41	0	2
91	Jacksonville gas, *Morgan*	1910[19]	1,320	2,000	0		*x*	0	53	0	0
92	Pittsfield (gas), *Pike*	1886[20]	8,960	0	0		*x*	0	68	0	0
93	Sparta, *Randolph*	1888[21]	165	*x*	0		*x*	0	20	0	0
94	Dupo, *St. Clair*	1928	670	1,879,000	28,000		*x*	0	295	0	8
95	Total for fields discovered prior to Jan. 1, 1937[22]		114,240	456,894,000	4,675,000		2,415.5	14.1	20,801	39	427
96	Beaver Creek, *Bond*	1942	30	8,000	5,000		0	0	2	0	0
97	Sorento, *Bond*	1938	30	4,000	0		0	0	3	0	0
98	Woburn, *Bond*	1940	210	402,000	59,000		0	0	28	0	0
99	Mt. Auburn, *Christian*	1943	40	3,000	3,000		0	0	1	1	0
100	Bible Grove South, *Clay*	1942	20	18,000	11,000		0	0	1	0	0
101	Clay City West, *Clay*	1941	320	958,000	109,000		0	0	14	0	0
102	Flora, *Clay*	1938	450	454,000	110,000		0	0	28	6	0
103			10	*x*	*x*		0	0	1	0	0
104			*x*	*x*	*x*		0	0	3	0	0
105			10	*x*	*x*		0	0	1	0	0
106			*x*	*x*	*x*		0	0	23	6	0
107	Ingraham, *Clay*	1942[23]	80	2,000	1,700		0	0	2	1	0

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[8] Total of lines 1, 36, 48, 58, 59.

[9] Abandoned 1923.

[10] Abandoned 1933.

[11] Abandoned 1934.

[12] Abandoned 1925, revived 1942.

[13] Abandoned 1935.

[14] Abandoned 1934.

[15] Abandoned 1919.

[16] Abandoned 1921.

[17] Abandoned 1904, revived 1942.

[18] Abandoned 1930, revived 1939.

[19] Abandoned 1937.

[20] Gas not used until 1905, abandoned 1930.

[21] Abandoned 1900.

[22] Total of lines 66 to 94 inclusive. Cumulative oil production total based on U. S. Bureau of Mines monthly report.

[23] Abandoned 1942, revived 1943.

TABLE 1.—(*Continued*)

	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.			Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
Line Number	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943	Secondary Recovery[h]	Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
59	0	298	0											AM	MisL	2,367
60	0	244	0	x	x		35.1	x	Biehl; Pen	S	P	1,425	20			
61	0	0	0	x	x		x	x	Waltersburg; MisU	S	P	1,540	15			
62	0	6	0	x	x		x	x	Tar Springs; MisU	S	P	1,620	20			
63	0	6	0	x	x		x	x	Cypress; MisU	S	P	1,920	10			
64	0	33	0	x	x		x	x	Bethel; MisU	S	P	2,010	9			
65	0	9	0	900	x		x	x	McClosky; MisL	L	P	2,280	8			
66	0	12,027	0													
67	0	0	9	335	x				Bethel; MisU	S	P	940	5	A	"Trenton"	3,044
68	0	0	0	x					Lindley (1st., 2d); MisU	S	P	927	x	A	Dev	2,290
69	0	66	0											D	St. Peter	4,213
70	0	44	0	x	x		36.2	0.20	Carlyle; MisU	S	P	984	24	D		
71	0	22	0	x	x		41.5	0.27	Devonian; Dev	L	P	2,429	9	D		
72	0	26	0	x	x		35.2	0.26	Carlyle; MisU	S	P	1,035	20	A	St. Peter	4,120
73	0	0	0	x	x		31.9	x	Carlyle; MisU	S	P	950	7	D	Cypress	962
74	0	0	0	x	x		x	x	Cypress; MisU	S	P	780	18	A	Dev	2,530
75	0	219	0	x	x		37.6	0.38	Hoing; Dev	S	P	447	21	A	"Trenton"	805
76	0	0	0	135			27.7	x	Unnamed; Pen	S	P	380	x	A	Pen	410
77	0	0	0	155					Unnamed; Pen	S	P	542	x	A	Pen	575
78	0	8	0	x	x		30.0	x	Unnamed; Pen	S	P	650	x	T	"Trenton"	2,560
79	0	0	0	x					Unnamed; Pen	S	P	305	x	D	Pen	495
80	0	0	0	145					Unnamed; Pen	S	P	461	x	A	"Trenton"	2,371
81	0	0	0	x			x	x	Dev-Sil	L	P	1,305	20	ML	Sil	1,500
82	0	12	0													
83	0	5	0	x	x		32.0	x	Dykstra, Wilson; Pen	S	P	610	20	D	MisL	2,001
84	0	7	0	x	x		32.0	x	Cypress; MisU	S	P	1,658	15	D	Dev	3,344
85	0	24	0											D	St. Peter	5,023
86	0	7	0	x	x		34.5	x	Benoist; MisU	S	P	1,540	20±	D		
87	0	17	0	x	x		38.0	0.38	Devonian; Dev	L	P	2,924	9	D		
88	0	20	0	x	x		30.2	x	Petro; Pen	S	P	720	20	D	MisL	1,760
89	0	1	0	x			23.0	0.42	Unnamed; Pen	S	P	664	x	D	Pen	681
90	0	4	0	x	x		30.2	0.79	"Trenton"; Ord	L	P	410	50	A	"Trenton"	845
91	0	0	0	x	x		x	x	Gas; Pen, MisL	S, SL	P	330	5	ML	"Trenton"	1,390
92	0	0	0	x	x				"Niagaran"; Sil	L	P	265	10	A	St. Peter	893
93	0	0	0	x	x		x	x	Cypress; MisU	S	P	850	7	D	MisU	985
94	0	85	0	x	x		32.7	0.70	"Trenton"; Ord	L	P	561	50	A	New Richmond	1,800
95		12,491	9													
96	0	2	0	x	x		34.2	0.25	Bethel; MisU	S	P	1,116	7	A	Dev	2,526
97	0	1	0	x	x		35.4	x	Dev	L	P	1,830	5	D	Dev	1,900
98	0	28	0	x	x		36.4	0.20	Bethel, MisU	S	P	1,010	11	A	Dev	2,455
99	0	1	0	x	x		36.6	0.28	Sil	L	P	1,900	5	A	Sil	1,905
100	0	1	0	x	x		x	x	Aux Vases, MisU	S	P	2,735	5	A	MisL	2,930
101	0	14	0	x	x		39.0	0.17	McClosky, MisL	L	P	3,050	15	A	MisL	3,080
102	0	22	0											D	MisL	3,100
103	0	1	0	x	x		x	x	Tar Springs; MisU	S	P	2,320	12			
104	0	3	0	x	x		x	x	Cypress; MisU	S	P	2,595	5			
105	0	1	0	x	x		37.4	x	Bethel; MisU	S	P	2,790	12			
106	0	17	0	x	x		37.2	0.24	McClosky; MisL	L	P	2,965	6			
107	0	1	0	x	x		x	x	McClosky; MisL	L	P	3,100	7	A	MisL	3,140

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
										1943	
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned
108	Iola, *Clay*	1939[24]	940	1.021,000	1,008,000		0	0	76	68	1
109			*x*	*x*	*x*		0	0			
110			*x*	*x*	*x*		0	0	4	4	0
111			*x*	*x*	*x*		0	0	4	3	0
112			*x*	*x*	*x*		0	0	34	28	1
113			*x*	*x*	*x*		0	0	9	9	0
114			*x*	*x*	*x*		0	0			
115									25	24	0
116	Kenner, *Clay*	1942	320	12,000	11,400		0	0	8	7	0
117			*x*	*x*	*x*		0	0	1	1	0
118	Sailor Springs Consolidated, *Clay*	1941	1,490	1,128,000	491,000		0	0	71	28	0
119			*x*	*x*	*x*		0	0			
120			*x*	*x*	*x*		0	0	31	8	0
121			*x*	*x*	*x*		0	0	34	19	0
122			*x*	*x*	*x*		0	0	5	0	0
123									1	1	0
124	Toliver, *Clay*	1942	40	5,000	3,000		0	0	1	0	0
125	Toliver East, *Clay*	1943	40	10,000	10,000		0	0	1	1	0
126	Xenia, *Clay*	1941	40	11,000	4,000		0	0	1	0	0
127	Clay City Consolidated, *Clay, Wayne*	1937	14,380	30,454,000	2,811,000		0	0	772	54	1
128			*x*	*x*	*x*		0	0	32	4	1
129			*x*	*x*	*x*		0	0	1	0	0
130			*x*	*x*	*x*		0	0	37	25	0
131			*x*	*x*	*x*		0	0	5	1	0
132			*x*	*x*	*x*		0	0	682	21	0
133									15	3	0
134	Bartelso South, *Clinton*	1942	50	7,000	6,000		0	0	2	1	0
135	Boulder, *Clinton*	1941	470	1,001,000	626,000		*x*	*x*	35	9	0
136			*x*	*x*	*x*		0	0	24	0	0
137			*x*	*x*	*x*		*x*	*x*	11	9	0
138	Centralia West, *Clinton*	1940	90	165,000	109,000		0	0	10	1	1
139	Hoffman, *Clinton*	1939	300	431,000	68,000		0	0	44	0	0
140			*x*	*x*	*x*		0	0	10	0	0
141			*x*	*x*	*x*		0	0	34	0	0
142	Posey, *Clinton*	1941	20	4,000	500		0	0	2	0	0
143	Centralia, *Clinton, Marion*	1937	2,850	24,066,000	1,706,000		0	0	906	0	35
144			*x*	*x*	*x*		0	0	23	0	0
145			*x*	*x*	*x*		0	0	562	0	10
146			*x*	12,830,000	942,000		0	0	319	0	25
147			*x*	28,000	4,000		0	0	2	0	0
148	Cooks Mills, *Coles*	1941[27]	20	5,000	1,000		0	0	2	0	1
149	Mattoon, *Coles*	1939[28]	40	33,000	10,000		0	0	3	1	0
150			10	*x*	*x*		0	0	1	0	0
151			10	*x*	*x*		0	0	1	1	0
152			20	*x*	*x*		0	0	1	0	0
153	New Bellair, *Crawford*	1942	20	7,000	2,000		0	0	2	0	0
154	Albion, *Edwards*	1940	900	2,708,000	369,000		0	0	90	9	1
155			*x*	*x*	*x*		0	0	3	0	0
156			*x*	*x*	*x*		0	0	14	4	1
157			*x*	*x*	*x*		0	0	3	3	0
158			*x*	*x*	*x*		0	0	2	0	0
159			*x*	*x*	*x*		0	0			
160			*x*	*x*	*x*		0	0	61	0	0
161									7	2	0
162	Albion East, *Edwards*	1943	250	35,000	35,000		0	0	6	6	0
163			*x*	*x*	*x*		0	0	1	1	0
164			*x*	*x*	*x*		0	0	3	3	0
165			*x*	*x*	*x*		0	0	1	1	0
166			*x*	*x*	*x*		0	0			
167									1	1	0
168	Albion North, *Edwards*	1942	20	5,000	2,000		0	0	1	0	0
169	Bone Gap, *Edwards*	1941	340	472,000	179,000		0	0	18	0	1

[24] Abandoned 1940, revived 1941.
[27] Abandoned 1943.
[28] Abandoned 1939, revived 1940.

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation					Structure[o]	Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg. End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net		Name	Depth of Hole, Ft.
108	0	74	0											D	MisL	2,590
109				x	x		x	x	Tar Springs; MisU[25]	S	P	1,890	9			
110	0	4	0	x	x		x	x	Weiler, MisU	S	P	2,125	20			
111	0	4	0	x	x		36.0	0.14	Bethel; MisU	S	P	2,290	14			
112	0	32	0	x	x		35.4	0.25	Aux Vases; MisU	S	P	2,335	11			
113	0	9	0	x	x		x	x	McClosky; MisL	L	P	2,425	10			
114				x	x		x	x	Paint Creek; MisU[25]	S	P	2,240	15			
115	0	25	0						[26]							
116	0	8	0	x	x		36.8	0.22	Bethel; MisU	S	P	2,660	7	A	MisL	2,975
117	0	1	0	x	x		x	x	Aux Vases; MisU[25]	S	P	2,810	20			
118	0	71	0											D	MisL	3,085
119				x	x		x	x	Glen Dean; MisU[25]	L	P	2,390	15			
120	0	31	0	x	x		39.5	0.17	Tar Springs; MisU	S	P	2,340	15			
121	0	34	0	x	x		38.5	0.28	Cypress; MisU	S	P	2,590	10			
122	0	5	0	x	x		36.4	x	McClosky; MisL	L	P	3,010	5			
123	0	1	0						[26]							
124	0	1	0	x	x		37.1	x	McClosky; MisL	L	P	2,790	9	A	MisL	2,890
125	0	1	0	x	x		x	x	McClosky; MisL	L	P	2,840	10	A	MisL	2,850
126	0	1	0	x	x		35.2	x	Aux Vases; MisU	S	P	2,785	12	D	Dev	4,970
127	0	739	0			W								A	Dev	4,840
128	0	29	0	x	x		37.9	x	Cypress; MisU	S	P	2,670	10			
129	0	1	0	x	x		38.0	x	Bethel; MisU	S	P	2,880	5			
130	0	36	0	x	x		38.0	x	Aux Vases; MisU	S	P	2,910	15			
131	0	5	0	x	x		38.0	x	Rosiclare; MisL	S	P	2,970	4			
132	0	653	0	x	x		38.5	x	McClosky; MisL	L	P	2,980	10			
133	0	15							[26]							
134	0	2	0	x	x		40.0	0.15	Dev	L	P	2,465	15	D	Dev	2,480
135	0	32	3											D	Dev	2,670
136	0	24	0	x	x		36.0	x	Bethel; MisU	S	P	1,195	10			
137	0	8	3	x	x		28.2	0.33	Dev	L	P	2,620	x			
138	0	9	0	x	x		37.8	0.17	Bethel; MisU	S	P	1,410	7	D	MisU	1,450
139	0	44	0											D	Dev	2,914
140	0	10	0	x	x		x	x	Cypress; MisU	S	P	1,185	9			
141	0	34	0	x	x		32.2	0.21	Bethel; MisU	S	P	1,320	7			
142	0	2	0	x	x		36.1	0.17	Cypress; MisU	S	P	1,105	5	D	MisU	1,265
143	0	704	0											A	"Trenton"	4,070
144	0	21	0	x	x		36.4	0.20	Cypress, MisU	S	P	1,200	15			
145	0	507	0	x	25+		37.7	0.17	Bethel; MisU	S	P	1,355	20			
146	0	175	0	x	200+		37.4	0.38	Dev	L	P	2,860	14			
147	0	1	0	x	x		43.2	0.28	"Trenton"; Ord	L	P	4,020	40			
148	0	0	0	x	x		36.4	0.40	Aux Vases; MisU	S	P	1,825	10	A	MisU	1,873
149	0	2	0											A	Shakopee	4,915
150	0	0	0	x	x		44.1	0.16	Cypress; MisU	S	P	1,835	25			
151	0	1	0	x	x		x	x	Aux Vases; MisU	S	P	2,010	15			
152	0	1	0	x	x		36.6	0.29	McClosky; MisL	L	P	2,000	12			
153	0	2	0	x	x		x	x	Pen	S	P	1,170	30	A	Dev	2,760
154	0	87	0											A	Dev	5,185
155	0	3	0	x	x		34.0	x	Bridgeport; Pen	S	P	1,570	10			
156	0	13	0	x	x		34.0	x	Waltersburg; MisU	S	P	2,365	10			
157	0	3	0	x	x		38.0	x	Bethel; MisU	S	P	2,935	14			
158	0	2	0	x	x		39.0	x	Aux Vases; MisU	S	P	3,040	16			
159				x	x		x	x	Levias; MisL[25]	L	P	3,100	10			
160	0	59	0	x	x		40.0	0.18	McClosky; MisL	L	P	3,110	11			
161	0	7	0						[26]					A	MisL	3,195
162	0	6	0													
163	0	1	0	x	x		x	x	Weiler; MisU	S	P	2,785	20			
164	0	3	0	x	x		x	x	Aux Vases; MisU	S	P	2,990	15			
165	0	1	0	x	x		x	x	Levias; MisL	L	P	3,090	8			
166				x	x		x	x	McClosky; MisL[25]	L	P	3,145	8			
167	0	1	0						[26]					A	MisU	3,260
168	0	1	0	x	x		x	x	Aux Vases; MisU	S	P	3,055	12	D	MisL	3,350
169	0	17	0	x	x		40.5	0.33	McClosky; MisL	L	P	3,265	8			

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[25] Producing in combination wells only.

[26] Wells producing from more than one sand, see Table 6.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
170	Browns, *Edwards*	1943	20	4,000	4,000		0	0	1	1	0
171	Browns South, *Edwards*	1943	20	500	500		0	0	1	1	0
172	Cowling, *Edwards*	1939	100	297,000	20,000		0	0	13	0	1
173	Ellery North, *Edwards*	1942[29]	20	3,000	2,000		0	0	1	0	1
174	Ellery South, *Edwards*	1943	80	7,000	7,000		0	0	2	2	0
175	Maplegrove, *Edwards*	1943	460	224,000	224,000		0	0	13	13	3
176	Samsville, *Edwards*	1942[30]	20	*x*	*x*		0	0	1	0	0
177	Lancaster West, *Edwards, Wabash*	1943	40	48,000	48,000		0	0	2	2	0
178			*x*	*x*	*x*		0	0	1	1	0
179			*x*	*x*	*x*		0	0	1	1	0
180	Bennington, *Edwards, Wayne*	1943	40	12,000	12,000		0	0	2	2	0
181	Ellery, *Edwards, Wayne*	1941	40	30,000	8,000		0	0	2	0	0
182	Grayville, *Edwards, White*	1939	160	438,000	296,000		0	0	20	0	0
183	Grayville West, *Edwards, White*	1941	30	40,000	17,000		0	0	3	0	0
184			10	*x*	*x*		0	0	1	0	0
185			20	*x*	*x*		0	0	2	0	0
186	Hill, *Effingham*	1943	40	9,000	9,000		0	0	2	2	0
187	Mason, *Effingham*	1940	100	160,000	17,000		0	0	9	0	1
188	Mason South, *Effingham*	1941	500	434,000	254,000		0	0	42	20	1
189			*x*	*x*	*x*		0	0	19	4	1
190			*x*	*x*	*x*		0	0	3	3	0
191			*x*	*x*	*x*		0	0	3	3	0
192			*x*	*x*	*x*		0	0	3	2	0
193									14	8	0
194	Bible Grove, *Effingham, Clay*	1942	1,710	1,039,000	749,000		0	0	68	35	1
195			*x*	*x*	*x*		0	0	60	34	1
196			*x*	*x*	*x*		0	0	8	1	0
197	Louden, *Effingham, Fayette*	1937	20,650	101,336,000	13,651,000		0	0	1,986	16	11
198			20,080	*x*	*x*		0	0	948	6	6
199			11,000	*x*	*x*		0	0	323	0	2
200			7,010	*x*	*x*		0	0	420	1	2
201			3,130	4,263,000	792,000		0	0	84	9	1
202									211	0	0
203	La Clede, *Fayette*	1943	40	500	500		0	0	1	1	0
204	St. James, *Fayette*	1938	1,900	6,783,000	1,128,000		0	0	191	1	1
205	St. Paul, *Fayette*	1941	170	175,000	90,000		0	0	13	0	0
206	Akin, *Franklin*	1942	140	141,000	105,000		0	0	7	4	0
207			*x*	*x*	*x*		0	0	3	0	0
208			*x*	*x*	*x*		0	0	3	3	0
209			*x*	*x*	*x*		0	0			
210									1	1	0
211	Benton, *Franklin*	1941	2,020	14,710,000	2,334,000		0	0	234	3	0
212	Benton North, *Franklin*	1941	110	199,000	70,000		0	0	12	1	0
213			*x*	*x*	*x*		0	0	3	0	0
214			*x*	*x*	*x*		0	0	2	0	0
215			*x*	*x*	*x*		0	0	2	0	0
216			*x*	*x*	*x*		0	0	1	0	0
217			*x*	*x*	*x*		0	0	1	0	0
218			*x*	*x*	*x*		0	0	2	0	0
219									1	1	0
220	Bessie, *Franklin*	1943	20	8,000	8,000		0	0	1	1	0
221	Sesser, *Franklin*	1942	40	31,000	13,000		0	0	3	0	0
222	Thompsonville, *Franklin*	1940	220	241,000	19,000		0	0	19	0	5
223	Valier, *Franklin*	1942	20	1,000	500		0	0	1	0	0
224	West Frankfort, *Franklin*	1941	60	137,000	137,000		0	0	10	7	0
225			*x*	*x*	*x*		0	0	9	7	0
226			*x*	*x*	*x*		0	0	1	0	0
227	West Frankfort South, *Franklin*	1943	100	52,000	52,000		0	0	8	8	0
228			*x*	*x*	*x*		0	0	6	6	0
229			*x*	*x*	*x*		0	0	2	2	0
230	Whittington, *Franklin*	1939	40	29,000	8,000		0	0	2	1	0
231			*x*	*x*	*x*		0	0	1	1	0
232			*x*	*x*	*x*		0	0	1	0	0

[29] Abandoned 1943.
[30] Abandoned 1942.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
170	0	1	0	x	x		x	x	Cypress; MisU	S	P	2,690	15	A	MisL	3,115
171	0	1	0	x	x		x	x	Bethel; MisU	S	P	2,835	18	A	MisL	3,140
172	0	11	0	x	x		36.6	0.23	Cypress; MisU	S	P	2,620	12	D	MisL	3,175
173	0	0	0	x	x		37.6	0.19	McClosky; MisL	L	P	3,420	7	A	MisL	3,495
174	0	2	0	x	x		x	x	McClosky; MisL	L	P	3,305	11	A	MisL	3,355
175	0	10	0	x	x		x	x	McClosky; MisL	L	P	3,270	8	A	MisL	3,300
176	0	0	0	x	x		x	x	Waltersburg; MisU	S	P	2,405	4	A	MisL	3,295
177	0	2	0											A	MisL	2,875
178	0	1	0	x	x		x	x	Levias; MisL	L	P	2,855	8			
179	0	1	0	x	x		x	x	Rosiclare; MisL	S	P	2,860	8			
180	0	2	0	x	x		x	x	Aux Vases; MisU	S	P	3,150	20	A	MisL	3,350
181	0	2	0	x	x		39.1	x	McClosky; MisL	L	P	3,340	12	D	MisL	3,355
182	0	15	0	x	x		35.8	0.31	McClosky; MisL	L	P	3,095	6	A	MisL	3,270
183	0	2	0											D	MisL	3,275
184	0	1	0	x	x		37.0	x	Cypress; MisU	S	P	2,870	20			
185	0	1	0	x	x		x	x	McClosky; MisL	L	P	3,170	8			
186	0	2	0	x	x		x	x	McClosky; MisL	L	P	2,570	9	A	MisL	2,655
187	0	8	0	x	x		38.4	0.21	McClosky; MisL	L	P	2,490	7	A	MisL	2,525
188	0	41	0											A	MisL	2,460
189	0	18	0	x	x		38.0	x	Bethel; MisU	S	P	2,305	11			
190	0	3	0	x	x		x	x	Aux Vases; MisU	S	P	2,360	14			
191	0	3	0	x	x		x	x	Rosiclare; MisL	S	P	2,435	8			
192	0	3	0	x	x		38.4	0.21	McClosky; MisL	L	P	2,450	7			
193	0	14	0						[26]							
194	0	66	0											D	MisL	2,970
195	0	58	0	x	x		38.0	0.13	Weiler; MisU	S	P	2,490	14			
196	0	8	0	x	x		36.2	x	McClosky; MisL	L	P	2,810	7			
197	185	1,766	0			P								A	St. Peter	4,680
198	35	907	0	x	268±		36.6	0.25	Cypress; MisU	S	P	1,495	22			
199	1	320	0	x	315±		37.8	0.24	Paint Creek; MisU	S	P	1,530	15			
200	1	413	0	x	319±		38.5	0.20	Bethel; MisU	S	P	1,550	16			
201	23	60	0	x	1,268		28.2	0.48	Dev	L	P	3,000	15			
202	125	66	0						[26]							
203	0	1	0	x	x		x	x	Bethel; MisU	S	P	2,335	20	A	MisU	2,360
204	0	183	0	x	x		34.4	0.31	Cypress; MisU	S	P	1,580	16	A	Dev	3,375
205	0	13	0	x	x		34.0	0.23	Bethel; MisU	S	P	1,885	6	D	MisU	1,905
206	0	7	0											A	MisL	3,280
207	0	3	0	x	x		32.0	x	Cypress; MisU	S	P	2,840	10			
208	0	3	0	x	x		37.8	0.12	Aux Vases; MisU	S	P	3,120	15			
209				x	x		x	x	McClosky; MisL[25]	L	P	3,270	9			
210	0	1	0						[26]							
211	0	232	0	x	x		41.7	0.12	Tar Springs; MisU	S	P	2,100	34	A	MisL	3,205
212	0	12	0											D	MisL	2,890
213	0	3	0	x	x		x	x	Paint Creek; MisU	S	P	2,595	10			
214	0	2	0	x	x		38.4	0.15	Bethel; MisU	S	P	2,605	10			
215	0	2	0	x	x		39.0	0.15	Aux Vases; MisU	S	P	2,690	10			
216	0	1	0	x	x		37.4	0.17	Levias; MisL	L	P	2,745	8			
217	0	1	0	x	x		38.4	0.15	Rosiclare; MisL	S	P	2,780	7			
218	0	2	0	x	x		x	x	McClosky; MisL	L	P	2,783	5			
219	0	1	0						[26]							
220	0	1	0	x	x		38.8	0.15	Levias; MisL	L	P	3,020	11	A	MisL	3,460
221	0	3	0	x	x		39.2	0.17	Aux Vases; MisU	S	P	2,700	7	D	MisL	2,925
222	0	10	0	x	x		37.8	0.16	McClosky; MisL	L	P	3,120	10	A	MisL	3,135
223	0	1	0	x	x		x	x	McClosky; MisL	L	P	2,715	12	A	MisL	2,725
224	0	10	0											D	MisL	2,995
225	0	9	0	x	x		38.4	0.13	Tar Springs; MisU	S	P	2,055	14			
226	0	1	0	x	x		x	x	Aux Vases; MisU	S	P	2,700	15			
227	0	8	0											A	MisL	2,930
228	0	6	0	x	x		x	x	Tar Springs; MisU	S	P	2,040	15			
229	0	2	0	x	x		37.2	0.23	Levias; MisL	L	P	2,765	8			
230	0	2	0											D	MisL	3,115
231	0	1	0	x	x		x	x	Cypress; MisU	S	P	2,540	15			
232	0	1	0	x	x		37.6	0.24	McClosky-St. Louis; MisL	L	P	2,870	9			

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
233	Inman, *Gallatin*	1940	60	47,000	19,000		0	0	8	3	0
234			*x*	*x*	*x*		0	0	3	1	0
235			*x*	*x*	*x*		0	0	2	1	0
236			*x*	*x*	*x*		0	0	2	1	0
237			*x*	*x*	*x*		0	0	1	0	0
238	Inman East, *Gallatin*	1940	810	1,692,000	710,000		0	0	81	20	1
239			*x*	*x*	*x*		0	0	3	0	0
240			*x*	*x*	*x*		0	0			
241			*x*	*x*	*x*		0	0			
242			*x*	*x*	*x*		0	0	1	1	0
243			*x*	*x*	*x*		0	0	6	3	0
244			*x*	*x*	*x*		0	0	44	7	1
245			*x*	*x*	*x*		0	0			
246			*x*	*x*	*x*		0	0	10	2	0
247			*x*	*x*	*x*		0	0	4	1	0
248									13	6	0
249	Inman North, *Gallatin*	1941	50	10,000	1,000		0	0	3	0	2
250			*x*	*x*	*x*		0	0	1	0	1
251			*x*	*x*	*x*		0	0	2	0	1
252	Inman West, *Gallatin*	1942	275	205,000	173,000		0	0	20	15	0
253			*x*	*x*	*x*		0	0	1	1	0
254			*x*	*x*	*x*		0	0	13	8	0
255			*x*	*x*	*x*		0	0			
256									6	6	0
257	Junction, *Gallatin*	1939	150	192,000	15,000		0	0	14	0	0
258	Omaha, *Gallatin*	1940	260	809,000	183,000		*x*	*x*	21	0	0
259			*x*	*x*	*x*		0	0	17	0	0
260			*x*	*x*	*x*		*x*	*x*	4	0	0
261	Belle Prairie, *Hamilton*	1940	40	86,000	27,000		0	0	2	0	0
262	Blairsville, *Hamilton*	1942	650	658,000	603,000		0	0	24	14	0
263			*x*	*x*	*x*		0	0	18	8	0
264			*x*	*x*	*x*		0	0	1	1	0
265			*x*	*x*	*x*		0	0			
266			*x*	*x*	*x*		0	0	3	3	0
267									2	2	0
268	Bungay, *Hamilton*	1941	410	106,000	100,000		0	0	13	12	0
269	Dahlgren, *Hamilton*	1941	540	862,000	54,000		0	0	42	0	4
270	Dale-Hoodville Consolidated, *Hamilton*	1940	4,640	16,108,000	3,882,000		0	0	402	38	10
271			*x*	*x*	*x*		0	0	21	21	0
272			*x*	*x*	*x*		0	0	37	2	0
273			*x*	*x*	*x*		0	0	87	0	5
274			*x*	*x*	*x*		0	0	185	13	5
275			*x*	*x*	*x*		0	0	2	1	0
276			*x*	*x*	*x*		0	0	24	0	0
277									46	1	0
278	Rural Hill, *Hamilton*	1941	2,535	7,052,000	1,711,000		0	0	195	23	1
279			*x*	*x*	*x*		0	0	1	0	0
280			*x*	*x*	*x*		0	0	94	16	1
281			*x*	*x*	*x*		0	0	12	4	0
282			*x*	*x*	*x*		0	0	2	2	0
283			*x*	*x*	*x*		0	0	25	0	0
284									61	1	0
285	Walpole, *Hamilton*	1941	1,100	1,811,000	900,000		0	0	58	25	0
286			*x*	*x*	*x*		0	0	2	1	0
287			*x*	*x*	*x*		0	0	56	24	0
288	Elkville, *Jackson*	1941	10	2,000	1,000		0	0	1	0	0
289	Bogota, *Jasper*	1943	125	53,000	53,000		0	0	6	6	0
290	Boos North, *Jasper*	1940	1,075	2,245,000	596,000		0	0	63	3	1
291	Hidalgo, *Jasper*	1940[31]	20	10,000	1,000		0	0	1	0	1
292	Ste. Marie, *Jasper*	1941	430	428,000	98,000		0	0	20	0	2
293	Belle Rive, *Jefferson*	1943	100	70,000	70,000		0	0	5	5	0
294	Coil West, *Jefferson*	1942	100	36,000	35,000		0	0	4	3	0
295	Cravat, *Jefferson*	1939	100	195,000	29,000		0	0	11	0	0
296	Divide, *Jefferson*	1943	110	26,000	26,000		0	0	3	3	0

[31] Abandoned 1943.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg., Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
233	0	8	0											D	MisL	3,010
234	0	3	0	x	x		36.0	x	Palestine; MisU	S	P	1,830	10			
235	0	2	0	x	x		x	x	Waltersburg; MisU	S	P	1,990	10			
236	0	2	0	x	x		x	x	Aux Vases; MisU	S	P	2,745	13			
237	0	1	0	x	x		x	x	McClosky; MisL	L	P	2,730	10			
238	0	80	0											A	MisL	2,915
239	0	3	0	x	x		24.4	0.31	Pen	S	P	780	12			
240				x	x		x	x	Degonia; MisU[25]	S	P	1,690	5			
241				x	x		x	x	Clore; MisU[25]	L	P	1,725	12			
242	0	1	0	x	x		x	x	Palestine; MisU	S	P	1,840	13			
243	0	6	0	x	x		x	x	Waltersburg; MisU	S	P	1,980	23			
244	0	43	0	x	x		34.6	0.24	Tar Springs; MisU	S	P	2,080	15			
245				x	x		x	x	Hardinsburg; MisU[25]	S	P	2,135	8			
246	0	10	0	x	x		35.2	0.23	Cypress; MisU	S	P	2,430	10			
247	0	4	0	x	x		x	x	McClosky; MisL	L	P	2,805	10			
248	0	13	0						[26]							
249	0	1	0											D	MisL	3,020
250	0	0	0	x	x		x	x	Aux Vases; MisU	S	P	2,815	25			
251	0	1	0	x	x		36.6	0.19	McClosky; MisL	L	P	2,850	15			
252	0	20	0											D	MisL	2,990
253	0	1	0	x	x		x	x	Tar Springs; MisU	S	P	2,175	13			
254	0	13	0	x	x		38.0	x	Weiler; MisU	S	P	2,480	17			
255				x	x		x	x	McClosky; MisL[25]	L	P	2,875	8			
256	0	6	0						[26]							
257	0	14	0	x	x		37.2	0.22	Waltersburg; MisU	S	P	1,765	15	D	MisL	2,710
258	0	20	1											D	MisL	3,580
259	0	17	0	x	x		25.9	0.23	Palestine; MisU	S	P	1,690	20			
260	0	3	1	x	x		27.0	0.24	Tar Springs; MisU	S	P	1,880	10			
261	0	2	0	x	x		37.0	0.12	McClosky; MisL	L	P	3,465	6	D	MisL	3,580
262	0	24	0											D	MisL	3,530
263	0	18	0	x	x		38.1	x	Aux Vases; MisU	S	P	3,290	12			
264	0	1	0	x	x		x	x	Levias; MisL	L	P	3,340	10			
265				x	x		x	x	Rosiclare; MisL[25]	S	P	3,365	7			
266	0	3	0	x	x		38.6	0.13	McClosky; MisL	L	P	3,440	7			
267	0	2	0						[26]							
268	0	13	0	x	x		36.8	0.24	Aux Vases; MisU	S	P	3,275	15	D	MisL	3,515
269	0	36	0	x	x		38.7	0.18	McClosky; MisL	L	P	3,337	10	A	MisL	3,380
270	1	390	0			P								D	MisL	3,314
271	0	21	0	x	x		x	x	Tar Springs; MisU	S	P	2,430	6			
272	0	37	0	x	x		37.6	0.25	Cypress; MisU	S	P	2,680	18			
273	0	82	0	x	x		39.0	0.19	Bethel; MisU	S	P	2,890	20			
274	1	179	0	x	x		38.5	0.39	Aux Vases; MisU	S	P	2,970	30			
275	0	2	0	x	x		36.0	0.20	Levias; MisL	L	P	3,140	13			
276	0	23	0	x	x		39.0	x	McClosky; MisL	L	P	3,150	10			
277	0	46	0						[26]							
278	0	193	0											A	MisL	3,450
279	0	1	0	x	x		x	x	Cypress; MisU	S	P	2,705	22			
280	0	92	0	x	x		38.0	0.15	Aux Vases; MisU	S	P	3,135	25			
281	0	12	0	x	x		x	x	Levias; MisL	L	P	3,200	30			
282	0	2	0	x	x		38.6	x	Rosiclare; MisL	S	P	3,230	15			
283	0	25	0	x	x		38.6	0.19	McClosky; MisL	L	P	3,260	22			
284	0	61	0						[26]							
285	0	58	0											A	MisL	3,300
286	0	2	0	x	x		36.1	x	Tar Springs; MisU	S	P	2,465	8			
287	0	56	0	x	x		38.4	0.13	Aux Vases; MisU	S	P	3,050	30			
288	0	1	0	x	x		35.8	0.22	Paint Creek; MisU	S	P	2,000	11	D	MisL	2,387
289	0	6	0	x	x		x	x	McClosky; MisL	L	P	3,110	11	A	MisL	3,210
290	0	60	0	x	x		38.6	0.20	McClosky; MisL	L	P	2,790	8	A	MisL	2,950
291	0	0	0	x	x		38.6	0.20	McClosky; MisL	L	P	2,560	8	N	Dev	4,140
292	0	18	0	x	x		40.2	0.14	McClosky, MisL	L	P	2,825	8	A	MisL	2,935
293	0	5	0	x	x		39.4	0.15	McClosky; MisL	L	P	3,080	11	A	MisL	3,095
294	0	4	0	x	x		x	x	Levias-McClosky; MisL	L	P	2,790	16	A	MisL	2,980
295	0	11	0	x	x		35.4	0.23	Bethel; MisU	S	P	2,065	11	D	MisL	2,355
296	0	3	0	x	x		x	x	McClosky; MisL	L	P	2,725	9	A	MisL	2,880

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c] To End of 1943	Oil Production Total, Bbl.[c] During 1943	Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e] To End of 1943	Gas Production, Millions Cu. Ft.[e] During 1943	Number of Oil and/or Gas Wells[f] Completed to End of 1943	Number of Oil and/or Gas Wells[f] 1943 Completed	Number of Oil and/or Gas Wells[f] 1943 Abandoned
297	Elk Prairie, *Jefferson*	1938[32]	10	700	0		0	0	1	0	0
298	Ina, *Jefferson*	1938[33]	20	16,000	500		0	0	2	1	0
299	King, *Jefferson*	1942	1,100	289,000	258,000		0	0	23	18	0
300			*x*	*x*	*x*		0	0	16	13	0
301			*x*	*x*	*x*		0	0			
302			*x*	*x*	*x*		0	0	1	1	0
303			*x*	*x*	*x*		0	0			
304									6	4	0
305	Marcoe, *Jefferson*	1938[34]	20	12,500	0		0	0	2	0	0
306	Markham City, *Jefferson*	1942	320	576,000	416,000		0	0	17	5	0
307			*x*	*x*	*x*		0	0			
308			*x*	*x*	*x*		0	0	16	5	0
309									1	0	0
310	Markham City North, *Jefferson*	1943	150	75,000	75,000		0	0	7	7	0
311	Mt. Vernon, *Jefferson*	1943	100	20,000	20,000		0	0	5	5	0
312			*x*	*x*	*x*		0	0	3	3	0
313			*x*	*x*	*x*		0	0	1	1	0
314			*x*	*x*	*x*		0	0			
315									1	1	0
316	Nason, *Jefferson*	1943	20	500	500		0	0	1	1	0
317	Roaches, *Jefferson*	1938	160	428,000	40,000		0	0	11	1	2
318	Waltonville, *Jefferson*	1943	20	5,000	5,000		0	0	1	1	0
319	Woodlawn, *Jefferson*	1940	1,320	6,967,000	1,436,000		0	0	162	14	1
320			*x*	*x*	*x*		0	0	1	1	0
321			*x*	*x*	*x*		0	0	161	13	1
322	Dix, *Jefferson, Marion*	1938	1,510	3,541,000	530,000		0	0	84	3	1
323			*x*	*x*	*x*		0	0	83	3	1
324			*x*	*x*	*x*		0	0	1	0	0
325	Kell, *Jefferson, Marion*	1942	10	1,000	*x*		0	0	1	0	0
326	Beman, *Lawrence*	1942	20	2,000	2,000		0	0	1	0	0
327	Ruark, *Lawrence*	1941	10	2,000	1,500		0	0	1	0	0
328	Russellville gas, *Lawrence*	1937	1,720	0	0		5,526	1,236	59	5	0
329			270	0	0		*x*	*x*	16	5	0
330			1,650	0	0		*x*	*x*	43	0	0
331	St. Francisville East, *Lawrence*	1941	90	80,000	33,000		0	0	9	0	0
332	Carlinville North, *Macoupin*	1941	30	500	200		0	0	3	0	0
333	Plainview, *Macoupin*	1942	10	800	300		0	0	1	0	0
334	Marine, *Madison*	1943	120	18,000	18,000		0	0	4	4	0
335	St. Jacob, *Madison*	1942	1,040	685,000	424,000		0	0	33	10	0
336	Alma, *Marion*	1941	20	39,000	12,000		0	0	4	1	1
337	Exchange, *Marion*	1943	80	8,000	8,000		0	0	2	2	0
338	Patoka, *Marion*	1937	910	3,137,000	298,000		0	0	133	3	6
339			890	*x*	*x*		0	0	129	2	6
340			30	*x*	*x*		0	0	3	0	0
341			40	*x*	*x*		0	0	1	1	0
342	Patoka East, *Marion*	1941	430	1,813,000	470,000		0	0	59	3	1
343			*x*	*x*	*x*		0	0	54	3	1
344			*x*	*x*	*x*		0	0	5	0	0
345									1	1	0
346	Salem, *Marion*	1938	9,270	177,241,000	10,659,000		0	0	2,444	26	0
347			9,270	*x*	*x*		0	0	481	21	0
348			*x*	*x*	*x*		0	0	152	0	0
349			*x*	*x*	*x*		0	0	5	4	0
350			*x*	*x*	*x*		0	0	551	1	0
351			*x*	*x*	*x*		0	0	8	0	0
352			5,000	33,738,000	917,000		0	0	541	0	0
353			1,000	2,049,000	336,000		0	0			
354									706	0	0
355	Tonti, *Marion*	1939	430	6,278,000	689,000		0	0	58	3	0
356			*x*	*x*	*x*		0	0	5	0	0
357			*x*	*x*	*x*		0	0	15	0	0
358			*x*	*x*	*x*		0	0	31	2	0
359			*x*	1,466,000	88,000		0	0	6	0	0
360									1	1	0

[32] Abandoned 1940.

[33] Abandoned 1941.

[34] Abandoned 1941.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg. End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
297	0	0	0	x	x		x	x	McClosky; MisL	L	P	2,720	7	D	MisL	2,960
298	0	1	0	x	x		36.4	0.20	St. Louis; MisL	L	P	3,000	5	D	MisL	3,065
299	0	23	0											A	Dev	4,760
300	0	16	0	x	x		38.6	0.17	Aux Vases; MisU	S	P	2,740	22			
301				x	x		x	x	Levias; MisL[25]	L	P	2,770	11			
302	0	1	0	x	x		39.6	0.16	Rosiclare; MisL	S	P	2,815	10			
303				x	x		x	x	McClosky; MisL[25]	L	P	2,840	7			
304	0	6	0						[26]							
305	0	0	0	x	x		23.2	0.54	McClosky; MisL	L	P	2,745	11	D	MisL	3,066
306	0	17	0											A	MisL	3,215
307				x	x		x	x	Levias; MisL[25]	L	P	3,060	5			
308	0	16	0	x	x		38.2	0.08	McClosky; MisL	L	P	3,065	5			
309	0	1	0						[26]							
310	0	7	0	x	x		x	x	McClosky; MisL	L	P	3,115	7	A	MisL	3,130
311	0	5	0											A	MisL	2,905
312	0	3	0	x	x		x	x	Aux Vases; MisU	S	P	2,685	9			
313	0	1	0	x	x		x	x	McClosky; MisL	L	P	2,800	7			
314				x	x		x	x	Levias; MisL[25]	L	P	2,750	6			
315	0	1	0						[26]							
316	0	1	0	x	x		x	x	Rosiclare; MisL	S	P	2,765	7	A	MisL	2,805
317	0	9	0	x	x		37.0	0.22	Rosiclare-McClosky; MisL	L	P	2,185	22	D	Dev	3,840
318	0	1	0	x	x		37.8	0.14	Bethel; MisU	S	P	2,465	12	A	MisL	2,765
319	0	159	0											A	MisL	2,365
320	0	1	0	x	x		x	x	Cypress; MisU	S	P	1,780	11			
321	0	158	0	x	x		37.8	0.16	Bethel; MisU	S	P	1,960	24			
322	0	83	0			P								A	Dev	3,650
323	0	82	0	x	275		39.0	0.23	Bethel; MisU	S	P	1,950	13			
324	0	1	0	x	x		x	x	Rosiclare; MisL	S	P	2,100	8			
325	0	1	0	x	x		36.2	0.26	McClosky; MisL	L	P	2,625	2	A	MisL	2,720
326	0	1	0	x	x		x	x	McClosky; MisL	L	P	1,835	6	A	MisL	1,845
327	0	1	0	x	x		32.0	x	Buchanan; Pen	S	P	1,515	14	D	MisL	2,320
328	0	0	58											A	Dev	3,133
329	0	0	16	x	x				Bridgeport; Pen	S	P	760	15			
330	0	0	42	x	x				Buchanan; Pen	S	P	1,110	11			
331	0	9	0	x	x		39.8	0.21	Bethel; MisU	S	P	1,765	8	A	MisL	1,960
332	0	3	0	x	x		20.3	0.35	Pen	S	P	495	10	D	Pen	530
333	0	1	0	x	x		x	x	Pen	S	P	400	5	A	Pen	420
334	0	4	0	x	x		x	x	Sil	L	P	1,735		A	Ord	2,590
335	0	23	0	x	x		40.0	0.23	"Trenton"; Ord	L	P	2,280	30	A	Ord	2,485
336	0	2	0	x	x		37.1	x	Bethel-Rosiclare; MisU-L	S	P	1,930	21	A	Dev	3,692
337	0	2	0	x	x		x	x	McClosky; MisL	L	P	2,735	8	A	MisL	2,765
338	0	102	0											A	Dev	2,955
339	0	98	0	x	30		39.5	0.16	Bethel; MisU	S	P	1,425	25			
340	0	3	0	x	50		40.9	0.31	Rosiclare; MisL	S	P	1,560	10			
341	0	1	0	x	x		40.0	0.28	Dev	L	P	2,835	10			
342	0	58	0											A	MisL	1,740
343	0	53	0	x	x		36.1	0.23	Cypress; MisU	S	P	1,340	20			
344	0	5	0	x	x		36.1	0.23	Bethel; MisU	S	P	1,465	12			
345	0	1	0						[26]							
346	0	2,408	0			P								A	Prairie du Chien	5,655
347	0	468	0	x	x		38.5	0.20	Bethel; MisU	S	P	1,795	40			
348	0	145	0	x	x		38.6	0.21	Aux Vases; MisU	S	P	1,815	28			
349	0	5		0	x		39.0	x	Rosiclare; MisL	S	P	1,950	5			
350	0	530	0	x	x		39.0	x	McClosky; MisL	L	P	1,975	17			
351	0	8	0	x	x		39.0	x	Salem; MisL	L	P	2,155	17			
352	0	454	0	x	x		42.1	0.28	Dev	L	P	3,350	60			
353	0	99	0	x	x		42.0	x	"Trenton"; Ord	L	P	4,500	50			
354	0	699	0						[26]							
355	0	57	0											D	Dev	3,550
356	0	5	0	x	x		39.0	x	Bethel; MisU	S	P	1,930	20			
357	0	15	0	x	x		39.0	x	Aux Vases; MisU	S	P	2,005	30			
358	0	30	0	x	x		39.4	0.21	McClosky; MisL	L	P	2,135	15			
359	0	6	0	x	x		41.0	x	Dev	L	P	3,490	15			
360	0	1	0						[26]							

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
361	Fairman, *Marion, Clinton*	1939	490	905,000	164,000		0	0	25	0	0
362	Mt. Olive, *Montgomery*	1942	20	2,000	1,500		0	0	2	1	1
363	Raymond, *Montgomery*	1940	60	3,500	1,500		0	0	4	1	1
364	Waggoner, *Montgomery*	1940	40	5,500	1,500		0	0	4	0	0
365	Tamaroa, *Perry*	1942	50	3,000	1,000		0	0	3	0	0
366	Amity, *Richland*	1942	20	3,000	2,000		0	0	1	0	0
367	Bonpas, *Richland*	1941	40	63,000	18,000		0	0	1	0	0
368	Bonpas West, *Richland*	1941	260	101,000	20,000		0	0	12	2	2
369			10	*x*	*x*		0	0	1	0	0
370			10	*x*	*x*		0	0	1	0	0
371			140	*x*	*x*		0	0	10	2	2
372	Noble, *Richland*	1937	4,650	17,167,000	2,509,000		*x*	*x*	307	16	0
373			*x*	*x*	*x*		0	0	129	15	0
374			*x*	*x*	*x*		*x*	*x*	178	1	0
375	Olney, *Richland*	1937	585	1,370,000	152,000		0	0	42	3	4
376			*x*	*x*	*x*		0	0	1	1	0
377			*x*	*x*	*x*		0	0	41	2	4
378	Schnell, *Richland*	1938	160	275,000	101,000		0	0	11	7	0
379	Stringtown, *Richland*	1941	140	159,000	43,000		0	0	8	0	0
380	Parkersburg, *Richland, Edwards*	1941	710	2,783,000	674,000		0	0	36	0	0
381			*x*	*x*	*x*		0	0	1	0	0
382			*x*	*x*	*x*		0	0	35	0	0
383	Parkersburg West, *Richland, Edwards*	1943	80	11,000	11,000		0	0	2	2	0
384	Dundas Consolidated, *Richland, Jasper*	1939	6,580	10,406,000	964,000		0	0	281	2	9
385			100	*x*	*x*		0	0	5	1	0
386			20	*x*	*x*		0	0	2	0	0
387			*x*	*x*	*x*		0	0			
388			6,500	*x*	*x*		0	0	269	1	9
389			100						5	0	0
390	Dundas East, *Richland, Jasper*	1942	360	430,000	317,000		0	0	14	3	1
391	Eldorado, *Saline*	1941	40	6,000	2,000		0	0	2	0	0
392	Lakewood, *Shelby*	1941	20	23,000	7,000		0	0	2	0	0
393			10	*x*	*x*		0	0	1	0	0
394			10	*x*	*x*		0	0	1	0	0
395	Stewardson, *Shelby*	1939	70	40,000	9,000		0	0	5	2	2
396	Friendsville, *Wabash*	1942	320	143,000	133,000		0	0	29	22	1
397			*x*	*x*	*x*		0	0	9	6	0
398			*x*	*x*	*x*		0	0	1	1	0
399			*x*	*x*	*x*		0	0	9	6	1
400			*x*	*x*	*x*		0	0	2	1	0
401			*x*	*x*	*x*		0	0	5	5	0
402			*x*	*x*	*x*		0	0	1	1	0
403									2	2	0
404	Keensburg Consolidated, *Wabash*	1939	2,725	8,908,000	1,142,000		0	0	336	6	5
405			*x*	*x*	*x*		0	0	19	1	0
406			*x*	*x*	*x*		0	0	2	0	0
407			*x*	*x*	*x*		0	0	4	0	0
408			*x*	*x*	*x*		0	0	9	0	0
409			*x*	*x*	*x*		0	0	250	3	5
410			*x*	*x*	*x*		0	0	1	0	0
411			*x*	*x*	*x*		0	0	8	0	0
412			*x*	*x*	*x*		0	0	4	0	0
413			*x*	*x*	*x*		0	0	24	1	0
414									15	1	0
415	Keensburg East, *Wabash*	1939[35]	20	*x*	*x*		0	0	3	0	2
416	Maud, *Wabash*	1940	250	336,000	38,000		0	0	20	0	0
417			*x*	*x*			0	0	2	0	0
418			*x*	*x*			0	0	1	0	0
419			*x*	*x*			0	0	1	0	0
420			*x*	*x*			0	0	15	0	0
421									1	0	0

[35] Abandoned 1943.

TABLE 1.—(*Continued*)

	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.			Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
Line Number	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943	Secondary Recovery[h]	Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
361	0	24	0	*x*	*x*		38.2	0.21	Bethel; MisU	S	P	1,460	8	D	"Trenton"	4,100
362	0	1	0	*x*	*x*		33.2	0.16	Pen	S	P	600	2	D	Pen	602
363	0	2	0	*x*	*x*		34.8	0.22	Pen	S	P	580	18	D	Pen	600
364	0	4	0	*x*	*x*		28.0	0.21	Pen	S	P	610	14	D	Dev	1,785
365	0	3	0	*x*	*x*		*x*	*x*	Weiler; MisU	S	P	1,125	10	A	MisL	1,530
366	0	1	0	*x*	*x*		*x*	*x*	McClosky; MisL	L	P	2,960	7	A	MisL	3,090
367	0	1	0	*x*	*x*		37.8	0.23	McClosky; MisL	L	P	3,120	8	D	MisL	3,200
368	0	10	0											D	MisL	3,200
369	0	1	0	*x*	*x*		*x*	*x*	Bethel; MisU	S	P	2,930	10			
370	0	1	0	*x*	*x*		*x*	*x*	Levias; MisL	L	P	3,070	10			
371	0	8	0	*x*	*x*		38.1	*x*	McClosky; MisL	L	P	3,130	6			
372	0	279	1											A	MisL	3,200
373	0	128	0	*x*	*x*		38.0	0.27	Cypress; MisU	S	P	2,545	20			
374	0	151	1	*x*	*x*		39.0	0.17	McClosky; MisL	L	P	2,955	10			
375	0	33	0											A	MisL	3,220
376	0	1	0	*x*	*x*		*x*	*x*	Levias; MisL	L	P	3,060	8			
377	0	32	0	*x*	*x*		37.2	0.19	McClosky; MisL	L	P	3,050	9			
378	0	11	0	*x*	*x*		37.0	0.19	McClosky; MisL	L	P	3,010	6	D	MisL	3,175
379	0	8	0	*x*	*x*		39.8	0.24	McClosky; MisL	L	P	3,025	8	D	MisL	3,080
380	0	36	0											A	MisL	3,200
381	0	1	0	*x*	*x*		*x*	*x*	Weiler; MisU	S	P	2,830	18			
382	0	35	0	*x*	*x*		38.0	0.31	McClosky; MisL	L	P	3,120	12			
383	0	2	0	*x*	*x*		*x*	*x*	McClosky; MisL	L	P	3,250	5	A	MisL	3,260
384	0	268	0											A	Dev	4,585
385	0	5	0	*x*	*x*		37.0	*x*	Cypress; MisU	S	P	2,570	23			
386	0	2	0	*x*	*x*		38.0	*x*	Aux Vases; MisU	S	P	2,705	10			
387				*x*	*x*		*x*	*x*	Rosiclare; MisL[25]	S	P	2,845	5			
388	0	256	0	*x*	*x*		38.4	0.17	McClosky; MisL	L	P	2,870	13			
389	0	5	0						[26]							
390	0	13	0	*x*	*x*		*x*	*x*	McClosky; MisL	L	P	3,000	8	A	MisL	3,105
391	0	2	0	*x*	*x*		34.2	0.14	McClosky; MisL	L	P	2,945	5	A	MisL	3,000
392	0	2	0											D	MisL	1,875
393	0	1	0	*x*	*x*		29.6	*x*	Bethel; MisU	S	P	1,690	8			
394	0	1	0	*x*	*x*		31.7	0.23	Aux Vases; MisU	S	P	1,725	9			
395	0	3	0	*x*	*x*		37.8	0.18	Aux Vases; MisU	S	P	1,940	5	D	MisL	1,970
396	0	27	0											A	MisL	2,685
397	0	8	0	*x*	*x*		31.0	0.22	Biehl; Pen	S	P	1,760	21			
398	0	1	0	*x*	*x*		27.3	0.25	Palestine; MisU	S	P	1,785	13			
399	0	8	0	*x*	*x*		35.2	0.17	Cypress; MisU	S	P	2,295	12			
400	0	2	0	*x*	*x*		36.7	0.18	Bethel; MisU	S	P	2,465	10			
401	0	5	0	*x*	*x*		*x*	*x*	Levias; MisL	L	P	2,625	10			
402	0	1	0	*x*	*x*		*x*	*x*	McClosky; MisL	L	P	2,650	11			
403	0	2	0						[26]							
404	0	315	0											A	MisL	3,065
405	0	17	0	*x*	*x*		38.0	*x*	Biehl; Pen	S	P	1,720	14			
406	0	2	0	*x*	*x*		*x*	*x*	Clore; MisU	S	P	1,810	9			
407	0	4	0	*x*	*x*		*x*	*x*	Palestine; MisU	S	P	1,830	16			
408	0	9	0	*x*	*x*		*x*	*x*	Tar Springs; MisU	S	P	2,060	15			
409	0	232	0	*x*	*x*		38.6	0.29	Cypress; MisU	S	P	2,445	18			
410	0	1	0	*x*	*x*		*x*	*x*	Paint Creek; MisU	S	P	2,550	12			
411	0	8	0	*x*	*x*		36.6	*x*	Bethel; MisU	S	P	2,570	18			
412	0	4	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	2,760	30			
413	0	23	0	*x*	*x*		37.9	0.38	McClosky; MisL	L	P	2,790	7			
414	0	15	0						[26]							
415	0	0	0	*x*	*x*		37.6	0.26	McClosky; MisL	L	P	2,705	6	D	MisL	2,715
416	0	17	0											D	MisL	2,670
417	0	2	0	*x*	*x*		37.7	*x*	Waltersburg; MisU	S	P	1,935	21			
418	0	1	0	*x*	*x*		*x*	*x*	MisU	S	P	2,120	12			
419	0	1	0	*x*	*x*		38.0	0.30	Rosiclare; MisL	S	P	2,640	9			
420	0	12	0	*x*	*x*		38.0	0.30	McClosky; MisL	L	P	2,650	8			
421	0	1	0						[26]							

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c] To End of 1943	Oil Production Total, Bbl.[c] During 1943	Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e] To End of 1943	Gas Production, Millions Cu. Ft.[e] During 1943	Number of Oil and/or Gas Wells[f] Completed to End of 1943	Number of Oil and/or Gas Wells[f] 1943 Completed	Number of Oil and/or Gas Wells[f] 1943 Abandoned
422	Mt. Carmel, *Wabash*	1940	3,025	3,610,000	871,000		0	0	286	87	4
423			*x*	*x*	*x*		0	0	40	10	0
424			*x*	*x*	*x*		0	0	1	0	0
425			*x*	*x*	*x*		0	0	1	0	0
426			*x*	*x*	*x*		0	0	182	52	4
427			*x*	*x*	*x*		0	0	2	1	0
428			*x*	*x*	*x*		0	0	2	0	0
429			*x*	*x*	*x*		0	0	32	9	0
430									26	15	0
431	Mt. Carmel West, *Wabash*	1939	60	9,000	8,000		0	0	4	2	0
432	Patton, *Wabash*	1940	40	5,000	1,500		0	0	5	1	0
433			30	*x*	*x*		0	0	4	1	0
434			20	*x*	*x*		0	0	1	0	0
435	Patton West, *Wabash*	1943	80	17,000	17,000		0	0	4	4	0
436			*x*	*x*	*x*		0	0	2	2	0
437			*x*	*x*	*x*		0	0	2	2	0
438	Lancaster, Wabash, *Lawrence*	1940	400	545,000	60,000		0	0	34	4	0
439			*x*	*x*	*x*		0	0	5	4	0
440			*x*	*x*	*x*		0	0	29	0	0
441	Cordes, *Washington*	1939	1,500	2,544,000	383,000		0	0	138	7	0
442	Dubois, *Washington*	1939	140	105,000	21,000		0	0	10	0	0
443	Dubois West, *Washington*	1942	10	4,000	2,000		0	0	1	0	0
444	Irvington, *Washington*	1940	800	2,854,000	551,000		0	0	85	2	0
445			*x*	*x*	*x*		0	0	2	1	0
446			*x*	*x*	*x*		0	0	75	1	0
447			*x*	*x*	104,000		0	0	7	0	0
448									1	0	0
449	McKinley, *Washington*	1940	80	167,000	31,000		0	0	7	1	1
450			50	*x*	*x*		0	0	6	1	0
451			*x*	*x*	*x*		0	0	1	0	1
452	Aden North, *Wayne*	1938	1,160	3,063,000	305,000		0	0	67	1	0
453			*x*	*x*	*x*		0	0	1	1	0
454			*x*	*x*	*x*		0	0	66	0	0
455	Barnhill, *Wayne*	1939	880	1,685,000	103,000		0	0	65	1	0
456			*x*	*x*	*x*		0	0	1	1	0
457			*x*	*x*	*x*		0	0	61	0	0
458			*x*	*x*	*x*		0	0	1	0	0
459									2	0	0
460	Barnhill East, *Wayne*	1939	625	266,000	231,000		0	0	19	14	2
461			*x*	*x*	*x*		0	0	5	3	0
462			*x*	*x*	*x*		0	0	1	1	0
463			*x*	*x*	*x*		0	0	1	0	0
464			*x*	*x*	*x*		0	0	9	7	2
465									3	3	0
466	Boyleston, *Wayne*	1938	2,480	3,484,000	461,000		0	0	117	3	4
467			*x*	*x*	*x*		0	0	1	1	0
468			*x*	*x*	*x*		0	0	1	0	0
469			*x*	*x*	*x*		0	0	1	0	0
470			*x*	*x*	*x*		0	0	111	2	4
471									3	0	0
472	Cisne, *Wayne*	1937	920	2,792,000	152,000		0	0	48	0	0
473			*x*	*x*	*x*		0	0	2	0	0
474			*x*	*x*	*x*		0	0	1	0	0
475			*x*	*x*	*x*		0	0	45	0	0
476	Cisne North, *Wayne*	1942	20	7,000	5,000		0	0	2	1	0
477	Coil, *Wayne*	1942	400	590,000	337,000		0	0	16	2	1
478			*x*	*x*	*x*		0	0	14	2	1
479			*x*	*x*	*x*		0	0	2	0	0
480	Covington, *Wayne*	1942	1,620	2,071,000	1,001,000		0	0	46	14	0
481			*x*	*x*	*x*		0	0	1	0	0
482			*x*	*x*	*x*		0	0	9	5	0
483			*x*	*x*	*x*		0	0	33	8	0
484									3	1	0
485	Covington South, *Wayne*	1943	280	51,000	51,000		0	0	7	7	0
486	Fairfield, *Wayne*	1942	20	5,000	4,000		0	0	1	0	0

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
422	0	276	0											A	MisL	2,475
423	0	37	0	*x*	*x*		32.0	*x*	Biehl; Pen	S	P	1,450	14			
424	0	1	0	*x*	*x*		*x*	*x*	Palestine; MisU	S	P	1,540	10			
425	0	1	0	*x*	*x*		*x*	*x*	Tar Springs; MisU	S	P	1,790	4			
426	0	175	0	*x*	*x*		38.4	*x*	Cypress; MisU	S	P	2,035	15			
427	0	2	0	*x*	*x*		*x*	*x*	Bethel; MisU	S	P	2,100	15			
428	0	2	0	*x*	*x*		36.6	0.36	Rosiclare; MisL	S	P	2,360	4			
429	0	32	0	*x*	*x*		38.4	0.42	McClosky; MisL	L	P	2,370	10			
430	0	26	0						[26]							
431	0	3	0	*x*	*x*		30.0	0.25	Tar Springs, MisU	S	P	1,940	15	D	MisL	2,555
432	0	4	0											A	MisL	2,315
433	0	3	0	*x*	*x*		*x*	*x*	Biehl; Pen	S	P	1,470	15			
434	0	1	0	*x*	*x*		*x*	*x*	McClosky; MisL	L	P	2,310	4			
435	0	4	0											A	MisL	2,415
436	0	2	0	*x*	*x*		*x*	*x*	Rosiclare; MisL	S	P	2,325	6			
437	0	2	0	*x*	*x*		*x*	*x*	McClosky; MisL	L	P	2,360	9			
438	0	24	0											A	MisL	2,765
439	0	5	0	*x*	*x*		*x*	*x*	Bethel; MisU	S	P	2,535	11			
440	0	19	0	*x*	*x*		39.8	0.28	McClosky; MisL	L	P	2,685	9			
441	0	137	0	*x*	*x*		37.4	0.19	Bethel; MisU	S	P	1,260	17	A	MisL	1,550
442	0	10	0	*x*	*x*		38.0	0.26	Bethel; MisU	S	P	1,360	11	D	Dev	3,535
443	0	1	0	*x*	*x*		*x*	*x*	Bethel; MisU	S	P	1,345	6	A	MisL	1,685
444	0	84	0											A	Dev	3,150
445	0	2	0	*x*	*x*		*x*	*x*	Weiler; MisU	S	P	1,385	14			
446	0	74	0	*x*	*x*		37.6	0.16	Bethel; MisU	S	P	1,535	10			
447	0	7	0	*x*	*x*		39.0	0.27	Dev	L	P	3,090	5			
448	0	1	0						[26]							
449	0	5	0											D	Dev	2,565
450	0	5	0	*x*	*x*		44.1	0.18	Bethel; MisU	S	P	980	14			
451	0	0	0	*x*	*x*		41.7	*x*	Dev	L	P	2,250	4			
452	0	62	0											A	Dev	5,395
453	0	1	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	3,200	15			
454	0	61	0	*x*	*x*		39.0	0.17	McClosky; MisL	L	P	3,320	12			
455	0	61	0											A	MisL	3,855
456	0	1	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	3,225	14			
457	0	57	0	*x*	*x*		37.6	0.17	McClosky; MisL	L	P	3,385	11			
458	0	1	0	*x*	*x*		*x*	*x*	Salem; MisL	L	P	3,792	8			
459	0	2	0						[26]							
460	0	16	0											D	MisL	3,530
461	0	4	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	3,240	12			
462	0	1	0	*x*	*x*		*x*	*x*	Levias; MisL	L	P	3,285	8			
463	0	1	0	*x*	*x*		*x*	*x*	Rosiclare; MisL	S	P	3,320	5			
464	0	7	0	*x*	*x*		34.4	0.18	McClosky; MisL	L	P	3,375	7			
465	0	3	0						[26]							
466	0	110	0											A	MisL	3,495
467	0	1	0	*x*	*x*		39.6	*x*	Aux Vases; MisU	S	P	3,090	12			
468	0	1	0	*x*	*x*		*x*	*x*	Levias; MisL	L	P	3,215	11			
469	0	1	0	*x*	*x*		40.2	0.14	Rosiclare; MisL	S	P	3,250	4			
470	0	104	0	*x*	*x*		40.2	0.14	McClosky; MisL	L	P	3,260	14			
471	0	3	0						[26]							
472	0	46	0											A	St. Peter	7,205
473	0	2	0	*x*	*x*		38.5	*x*	Aux Vases; MisU	S	P	2,980	13			
474	0	1	0	*x*	*x*		*x*	*x*	Rosiclare; MisL	S	P	3,010	4			
475	0	43	0	*x*	*x*		35.8	0.24	McClosky; MisL	L	P	3,120	15			
476	0	2	0	*x*	*x*		39.0	*x*	McClosky; MisL	L	P	3,170	10	A	MisL	3,245
477	0	14	0											A	MisL	3,180
478	0	12	0	*x*	*x*		37.1	0.20	Aux Vases; MisU	S	P	2,860	16			
479	0	2	0	*x*	*x*		37.5	*x*	McClosky; MisL	L	P	2,970	3			
480	0	46	0											D	MisL	3,325
481	0	1	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	3,115	18			
482	0	9	0	*x*	*x*		40.0	*x*	Levias; MisL	L	P	3,210	5			
483	0	33	0	*x*	*x*		40.0	*x*	McClosky; MisL	L	P	3,240	8			
484	0	3	0						[26]							
485	0	7	0	*x*	*x*		39.4	0.18	McClosky; MisL	L	P	3,310	11	A	MisL	3,365
486	0	1	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	3,235	14	A	MisL	3,390

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
487	Geff, *Wayne*	1941	300	413,000	293,000		0	0	19	4	0
488			*x*	*x*	*x*		0	0	12	0	0
489			*x*	*x*	*x*		0	0	7	4	0
490	Geff West, *Wayne*	1942	60	32,000	20,000		0	0	3	0	0
491	Goldengate, *Wayne*	1939	60	32,000	15,000		0	0	3	0	0
492			*x*	*x*	*x*		0	0	1	0	0
493			*x*	*x*	*x*		0	0	2	0	0
494	Johnsonville, *Wayne*	1941	4,120	12,867,000	2,199,000		0	0	247	0	2
495			*x*	*x*	*x*		0	0	33	0	0
496			*x*	*x*	*x*		0	0			
497			*x*	*x*	*x*		0	0	207	0	2
498									7	0	0
499	Johnsonville North, *Wayne*	1943	40	5,000	5,000		0	0	1	1	0
500	Johnsonville South, *Wayne*	1942	20	11,000	9,000		0	0	2	0	0
501			*x*	*x*	*x*		0	0	1	0	0
502			*x*	*x*	*x*		0	0	1	0	0
503	Johnsonville West, *Wayne*	1942[36]	40	1,500	*x*		0	0	2	1	0
504			*x*	*x*	*x*		0	0	1	1	0
505			*x*	*x*	*x*		0	0	1	0	0
506	Leech Township, *Wayne*	1938	240	401,000	48,000		0	0	14	0	0
507	Mayberry, *Wayne*	1941	330	161,000	55,000		0	0	6	0	1
508	Mt. Erie, *Wayne*	1938	380	308,000	211,000		0	0	20	9	0
509			*x*	*x*	*x*		0	0	9	6	0
510			*x*	*x*	*x*		0	0	1	0	0
511			*x*	*x*	*x*		0	0	9	3	0
512									1	0	0
513	Mt. Erie South, *Wayne*	1939[37]	360	50,000	41,000		0	0	9	7	2
514			*x*	*x*	*x*		0	0	4	4	0
515			*x*	*x*	*x*		0	0	2	2	0
516			*x*	*x*	*x*		0	0	1	0	1
517			*x*	*x*	*x*		0	0	2	1	1
518	Rinard, *Wayne*	1937[38]	20	15,000	*x*		0	0	2	1	1
519			*x*	*x*	*x*		0	0	1	1	1
520			*x*	*x*	*x*		0	0	1	0	0
521	Sims, *Wayne*	1941	1,660	2,614,000	950,000		0	0	60	4	1
522			*x*	*x*	*x*		0	0	12	2	0
523			*x*	*x*	*x*		0	0			
524			*x*	*x*	*x*		0	0			
525			*x*	*x*	*x*		0	0	30	2	1
526									18	0	0
527	Sims North, *Wayne*	1942	720	600,000	525,000		0	0	29	22	1
528			*x*	*x*	*x*		0	0	20	19	1
529			*x*	*x*	*x*		0	0			
530			*x*	*x*	*x*		0	0	3	0	0
531			*x*	*x*	*x*		0	0	4	2	0
532									2	1	0
533	Aden, Wayne, *Hamilton*	1938	880	821,000	291,000		0	0	20	10	0
534			*x*	*x*	*x*		0	0	1	1	0
535			*x*	*x*	*x*		0	0	9	0	0
536			*x*	*x*	*x*		0	0			
537			*x*	*x*	*x*		0	0			
538									10	9	0
539	Burnt Prairie, *White*	1940	270	380,000	53,000		0	0	20	0	1
540			*x*	*x*	*x*		0	0	2	0	0
541			*x*	*x*	*x*		0	0	18	0	1
542	Calvin North, *White*	1943	210	128,000	128,000		0	0	24	24	1
543			*x*	*x*	*x*		0	0	13	13	1
544			*x*	*x*	*x*		0	0			
545			*x*	*x*	*x*		0	0	1	1	0
546			*x*	*x*	*x*		0	0	4	4	0
547			*x*	*x*	*x*		0	0	1	1	0
548			*x*	*x*	*x*		0	0	4	4	0
549									1	1	0

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[36] Abandoned 1942, revived 1943.
[37] Abandoned 1941, revived 1942.
[38] Abandoned 1941.

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of hole, Ft.
487	0	19	0											D	MisL	3,320
488	0	12	0	*x*	*x*		40.4	0.13	Aux Vases; MisU	S	P	3,065	14			
489	0	7	0	*x*	*x*		34.0	0.33	McClosky; MisL	L	P	3,135	3			
490	0	3	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	3,130	12	D	MisL	3,320
491	0	1	0											D	Dev	5,645
492	0	1	0	*x*	*x*		*x*	*x*	Rosiclare; MisL	S	P	3,320	5			
493	0	0	0	*x*	*x*		34.4	0.18	McClosky; MisL	L	P	3,375	7			
494	0	245	0											A	MisL	3,390
495	0	33	0	*x*	*x*		39.4	0.41	Aux Vases; MisU	S	P	2,980	12			
496				*x*	*x*		*x*	*x*	Levias; MisL[25]	L	P	3,040	10			
497	0	205	0	*x*	*x*		39.4	0.16	McClosky; MisL	L	P	3,070	15			
498	0	7	0		*x*				[26]							
499	0	1	0	*x*	*x*		*x*	*x*	Levias-McClosky; MisL	L	P	3,190	9	A	MisL	3,320
500	0	2	0											A	MisL	3,240
501	0	1	0	*x*	*x*		39.0	*x*	Aux Vases; MisU	S	P	3,030	20			
502	0	1	0	*x*	*x*		*x*	*x*	McClosky; MisL	L	P	3,210	3			
503	0	1	0											A	MisL	3,185
504	0	1	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	2,970	15			
505	0	0	0	*x*	*x*		*x*	*x*	McClosky; MisL	L	P	3,105	6			
506	0	14	0	*x*	*x*		39.0	0.19	McClosky; MisL	L	P	3,415	11	D	MisL	3,485
507	0	5	0	*x*	*x*		38.0	0.16	McClosky; MisL	L	P	3,340	7	D	MisL	3,440
508	0	20	0											D	MisL	3,215
509	0	9	0	*x*	*x*		39.2	0.11	Aux Vases; MisU	S	P	2,975	17			
510	0	1	0	*x*	*x*		*x*	*x*	Rosiclare; MisL	S	P	3,070	7			
511	0	9	0	*x*	*x*		39.8	0.18	McClosky; MisL	L	P	3,080	10			
512	0	1	0						[26]							
513	0	6	0											D	MisL	3,380
514	0	4	0	*x*	*x*		37.2	0.14	Aux Vases; MisU	S	P	3,070	15			
515	0	2	0	*x*	*x*		*x*	*x*	Levias; MisL	L	P	3,120	8			
516	0	0	0	*x*	*x*		*x*	*x*	Rosiclare; MisL	S	P	3,255	9			
517	0	0	0	*x*	*x*		31.7	*x*	McClosky; MisL	L	P	3,265	11			
518	0	0	0											D	MisL	3,154
519	0	0	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	2,955	15			
520	0	0	0	*x*	*x*		38.5	*x*	McClosky; MisL	L	P	3,155	5			
521	0	58	0											A	MisL	3,305
522	0	12	0	*x*	*x*		40.4	0.20	Aux Vases; MisU	S	P	3,030	15			
523				*x*	*x*		39.1	*x*	Levias; MisL[25]	L	P	3,112	5			
524				*x*	*x*		*x*	*x*	Rosiclare; MisL[25]	S	P	3,130	8			
525	0	28	0	*x*	*x*		39.1	*x*	McClosky; MisL	L	P	3,170	8			
526	0	18	0						[26]					A	MisL	3,245
527	0	27	0													
528	0	19	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	3,130	10			
529				*x*	*x*		*x*	*x*	Levias; MisL[25]	L	P	3,145	8			
530	0	2	0	*x*	*x*		*x*	*x*	Rosiclare; MisL	S	P	3,150	8			
531	0	4	0	*x*	*x*		37.5	0.19	McClosky; MisL	L	P	3,185	4			
532	0	2	0						[26]					A	MisL	3,460
533	0	19	0													
534	0	1	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	3,175	15			
535	0	8	0	*x*	*x*		40.0	*x*	McClosky; MisL	L	P	3,285	7			
536				*x*	*x*		*x*	*x*	Levias; MisL[25]	L	P	3,290	5			
537				*x*	*x*		*x*	*x*	Rosiclare; MisL[25]	S	P	3,320	10			
538	0	10	0						[26]					D	MisL	3,435
539	0	19	0													
540	0	2	0	*x*	*x*		*x*	*x*	Rosiclare; MisL	S	P	3,260	9			
541	0	17	0	*x*	*x*		37.0	0.28	McClosky; MisL	L	P	3,425	11	A	MisL	3,100
542	0	23	0													
543	0	12	0	*x*	*x*		30.0	0.29	Pen	S	P	1,505	15			
544				*x*	*x*		*x*	*x*	Palestine; MisU[25]	S	P	1,995	11			
545	0	1	0	*x*	*x*		*x*	*x*	Waltersburg; MisU	S	P	2,255	15			
546	0	4	0	*x*	*x*		34.0	0.30	Tar Springs; MisU	S	P	2,330	17			
547	0	1	0	*x*	*x*		38.4	0.19	Bethel; MisU	S	P	2,815	11			
548	0	4	0	*x*	*x*		*x*	*x*	Aux Vases; MisU	S	P	2,875	18			
549	0	1	0						[26]							

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
550	Carmi, *White*	1940	30	5,000	1,000		0	0	2	0	0
551			*x*	*x*	*x*		0	0	1	0	0
552			*x*	*x*	*x*		0	0	1	0	0
553	Carmi North, *White*	1942	50	45,000	24,000		0	0	3	0	0
554	Centerville, *White*	1940	60	187,000	31,000		0	0	5	0	0
555	Centerville East, *White*	1941	600	974,000	471,000		0	0	40	4	0
556			*x*	*x*	*x*		0	0	23	3	0
557			*x*	*x*	*x*		0	0	1	0	0
558			*x*	*x*	*x*		0	0	1	0	0
559			*x*	*x*	*x*		0	0	4	0	0
560			*x*	*x*	*x*		0	0			
561			*x*	*x*	*x*		0	0	10	1	0
562									1	0	0
563	Concord, *White*	1942	160	28,000	20,000		0	0	7	6	0
564			*x*	*x*	*x*		0	0	3	3	0
565			*x*	*x*	*x*		0	0	3	2	0
566			*x*	*x*	*x*		0	0	1	1	0
567	Epworth, *White*	1941	110	156,000	56,000		0	0	11	1	0
568			*x*	*x*	*x*		0	0	2	0	0
569			*x*	*x*	*x*		0	0	7	0	0
570			*x*	*x*	*x*		0	0	1	0	0
571			*x*	*x*	*x*		0	0	1	1	0
572	Gossett, *White*	1943	40	500	500		0	0	1	1	0
573	Herald, *White*	1940	140	91,000	42,000		0	0	14	6	0
574			*x*	*x*	*x*		0	0	4	2	0
575			*x*	*x*	*x*		0	0	4	1	0
576			*x*	*x*	*x*		0	0	3	2	0
577			*x*	*x*	*x*		0	0	2	0	0
578			*x*	*x*	*x*		0	0	1	1	0
579	Iron, *White*	1940	770	2,701,000	311,000		0	0	64	0	2
580			*x*	*x*	*x*		0	0	5	0	0
581			*x*	*x*	*x*		0	0	33	0	1
582			*x*	*x*	*x*		0	0	2	0	0
583			*x*	*x*	*x*		0	0	1	0	0
584			*x*	*x*	*x*		0	0	20	0	1
585									3	0	0
586	Maunie, *White*	1941	60	20,000	7,000		0	0	6	4	0
587			*x*	*x*	*x*		0	0	1	1	0
588			*x*	*x*	*x*		0	0	2	0	0
589			*x*	*x*	*x*		0	0	2	2	0
590			*x*	*x*	*x*		0	0	1	1	0
591	Maunie North, *White*	1941	120	57,000	37,000		0	0	8	3	0
592			*x*	*x*	*x*		0	0	2	1	0
593			*x*	*x*	*x*		0	0			
594			*x*	*x*	*x*		0	0	5	1	0
595									1	1	0
596	Maunie South, *White*	1939	700	1,361,000	379,000		0	0	71	2	1
597			*x*	*x*	*x*		0	0	5	0	0
598			*x*	*x*	*x*		0	0	34	0	1
599			*x*	*x*	*x*		0	0	1	0	0
600			*x*	*x*	*x*		0	0	18	1	0
601			*x*	*x*	*x*		0	0	2	1	0
602			*x*	*x*	*x*		0	0	6	0	0
603			*x*	*x*	*x*		0	0	1	0	0
604			*x*	*x*	*x*		0	0	1	0	0
605									3	0	0
606	New Harmony Consolidated, *White*	1939	7,200	24,022,000	5,065,000		0	0	721	23	8
607			*x*	*x*	*x*		0	0	8	1	0
608			*x*	*x*	*x*		0	0	22	3	0
609			*x*	*x*	*x*		0	0	27	0	0
610			*x*	*x*	*x*		0	0	87	1	0
611			*x*	*x*	*x*		0	0	11	0	0
612			*x*	*x*	*x*		0	0	126	1	4
613			*x*	*x*	*x*		0	0	170	5	4
614			*x*	*x*	*x*		0	0	2	0	0
615			*x*	*x*	*x*		0	0	87	1	0
616									181	11	0

TABLE 1.—(*Continued*)

	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.			Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
Line Number	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943	Secondary Recovery[h]	Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
550	0	1	0											D	MisL	3,235
551	0	1	0	x	x		x	x	Levias; MisL	L	P	3,130	8			
552	0	0	0	x	x		x	x	McClosky; MisL	L	P	3,150	4			
553	0	3	0	x	x		37.0	0.14	Aux Vases; MisU	S	P	3,230	14	D	MisU	3,250
554	0	5	0	x	x		36.8	0.17	McClosky; MisL	L	P	3,355	4	D	MisL	3,375
555	0	39	0											D	MisL	3,365
556	0	23	0	x	x		37.2	0.20	Tar Springs; MisU	S	P	2,530	15			
557	0	1	0	x	x		x	x	Cypress; MisU	S	P	2,915	10			
558	0	1	0	x	x		x	x	Bethel; MisU	S	P	2,960	14			
559	0	3	0	x	x		x	x	Aux Vases; MisU	S	P	3,085	11			
560				x	x		x	x	Levias; MisL[25]	L	P	3,175	5			
561	0	10	0	x	x		40.0	x	McClosky; MisL	L	P	3,265	12			
562	0	1	0						[26]							
563	0	7	0											A	MisL	3,115
564	0	3	0	x	x		x	x	Tar Springs; MisU	S	P	2,270	19			
565	0	3	0	x	x		x	x	Aux Vases; MisU	S	P	2,905	10			
566	0	1	0	x	x		x	x	Levias; MisL	L	P	2,930	6			
567	0	10	0											D	MisL	3,195
568	0	2	0	x	x		x	x	Degonia; MisU	S	P	2,090	6			
569	0	6	0	x	x		36.2	x	Clore; MisU	S	P	2,070	18			
570	0	1	0	x	x		x	x	Palestine; MisU	S	P	2,100	14			
571	0	1	0	x	x		x	x	Bethel; MisU	S	P	2,825	16			
572	0	1	0	x	x		x	x	McClosky; MisL	L	P	3,080	6	A	MisL	3,090
573	0	11	0											A	MisL	3,175
574	0	4	0	x	x		28.0	x	Pen	S	P	1,565	6			
575	0	3	0	x	x		37.2	0.24	Tar Springs; MisU	S	P	2,260	18			
576	0	3	0	x	x		x	x	Cypress; MisU	S	P	2,655	10			
577	0	0	0	x	x		x	x	Bethel; MisU	S	P	2,790	8			
578	0	1	0	x	x		x	x	Aux Vases; MisU	S	P	2,920	13			
579	0	59	0											A	MisL	3,145
580	0	4	0	x	x		36.4	x	Tar Springs; MisU	S	P	2,425	6			
581	0	31	0	x	x		38.4	0.30	Hardinsburg; MisU	S	P	2,535	18			
582	0	2	0	x	x		38.0	x	Cypress; MisU	S	P	2,710	24			
583	0	1	0	x	x		x	x	Bethel; MisU	S	P	2,790	8			
584	0	18	0	x	x		39.0	0.20	McClosky; MisL	L	P	3,060	10			
585	0	3	0						[26]							
586	0	6	0											D	MisL	3,050
587	0	1	0	x	x		x	x	Pen	S	P	1,305	10			
588	0	2	0	x	x		38.0	x	Palestine; MisU	S	P	2,010	6			
589	0	2	0	x	x		x	x	Tar Springs; MisU	S	P	2,195	15			
590	0	1	0	x	x		x	x	Aux Vases; MisU	S	P	2,845	14			
591	0	8	0											D	MisL	3,110
592	0	2	0	x	x		36.5	x	Bethel; MisU	S	P	2,825	21			
593				x	x		x	x	Aux Vases; MisU[25]	S	P	2,930	20			
594	0	5	0	x	x		x	x	McClosky; MisL	L	P	3,075	6			
595	0	1	0						[26]							
596	0	68	0											A	MisL	3,030
597	0	5	0	x	x		37.0	x	Pen	S	P	1,455	25			
598	0	31	0	x	x		33.8	0.28	Palestine; MisU	S	P	2,020	18			
599	0	1	0	x	x		x	x	Waltersburg; MisU	S	P	2,210	19			
600	0	18	0	x	x		38.0	x	Tar Springs; MisU	S	P	2,255	15			
601	0	2	0	x	x		39.0	x	Cypress; MisU	S	P	2,560	8			
602	0	6	0	x	x		x	x	Aux Vases; MisU	S	P	2,845	22			
603	0	1	0	x	x		x	x	Levias; MisL	L	P	2,865	3			
604	0	1	0	x	x		x	x	McClosky; MisL	L	P	2,870	2			
605	0	3	0						[26]							
606	0	707	0			P								A	MisL	3,220
607	0	8	0	x	x		x	x	Biehl; Pen	S	P	1,830	40			
608	0	21	0	x	x		37.6	0.49	Waltersburg; MisU	S	P	2,155	20			
609	0	27	0	x	x		36.0	0.19	Tar Springs; MisU	S	P	2,225	15			
610	0	87	0	x	x		39.0	x	Cypress; MisU	S	P	2,560	25			
611	0	11	0	x	x		38.0	x	Paint Creek; MisU	S	P	2,660	20			
612	0	127	0	x	x		36.0	0.24	Bethel; MisU	S	P	2,685	25			
613	0	163	0	x	x		36.4	0.19	Aux Vases; MisU	S	P	2,820	10			
614	0	2	0	x	x		x	x	Rosiclare; MisL	S	P	2,905	15			
615	0	87	0	x	x		39.2	0.20	McClosky; MisL	L	P	2,920	8			
616	0	174	0						[26]							

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
										1943	
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned
617	New Harmony South, *White*	1941	60	45,000	10,000		0	0	4	0	0
618			*x*	*x*	*x*		0	0	1	0	0
619			*x*	*x*	*x*		0	0	1	0	0
620			*x*	*x*	*x*		0	0	1	0	0
621			*x*	*x*	*x*		0	0	1	0	0
622	New Haven, *White*	1941	250	387,000	88,000		0	0	22	1	0
623			*x*	*x*	*x*		0	0	4	0	0
624			*x*	*x*	*x*		0	0	1	0	0
625			*x*	*x*	*x*		0	0	7	0	0
626			*x*	*x*	*x*		0	0	5	1	0
627			*x*	*x*	*x*		0	0	1	0	0
628									4	0	0
629	Phillipstown Consolidated, *White*	1939	1,300	1,464,000	1,134,000		0	0	89	50	5
630			*x*	*x*	*x*		0	0	1	1	0
631			*x*	*x*	*x*		0	0	7	7	0
632			*x*	*x*	*x*		0	0	4	2	0
633			*x*	*x*	*x*		0	0	2	0	0
634			*x*	*x*	*x*		0	0	2	0	0
635			*x*	*x*	*x*		0	0	40	17	4
636			*x*	*x*	*x*		0	0			
637			*x*	*x*	*x*		0	0	6	6	0
638			*x*	*x*	*x*		0	0	2	0	0
639			*x*	*x*	*x*		0	0			
640			*x*	*x*	*x*		0	0	3	0	0
641			*x*	*x*	*x*		0	0	10	6	1
642									12	11	0
643	Stokes, *White*	1939	850	1,183,000	513,000		0	0	45	17	0
644			*x*	*x*	*x*		0	0	2	2	0
645			*x*	*x*	*x*		0	0	1	1	0
646			*x*	*x*	*x*		0	0	7	0	0
647			*x*	*x*	*x*		0	0	11	4	0
648			*x*	*x*	*x*		0	0	5	4	0
649			*x*	*x*	*x*		0	0	1	1	0
650			*x*	*x*	*x*		0	0	12	0	0
651									6	5	0
652	Storms, *White*	1939	1,510	4,136,000	460,000		0	0	156	0	6
653			*x*	*x*	*x*		0	0	152	0	6
654			*x*	*x*	*x*		0	0	1	0	0
655			*x*	*x*	*x*		0	0	3	0	0
656	Roland, *White, Gallatin*	1940	1,930	4,087,000	1,104,000		0	0	148	7	4
657			*x*	*x*	*x*		0	0	72	4	2
658			*x*	*x*	*x*		0	0	4	0	0
659			*x*	*x*	*x*		0	0	5	0	0
660			*x*	*x*	*x*		0	0			
661			*x*	*x*	*x*		0	0	15	0	0
662			*x*	*x*	*x*		0	0	19	2	1
663			*x*	*x*	*x*		0	0	2	1	0
664									31	0	1
665	Mill Shoals, *White*	1939	1,215	2,976,000	412,000		0	0	115	8	5
666			*x*	*x*	*x*		0	0	91	6	3
667			*x*	*x*	*x*		0	0	21	2	0
668									3	0	2
669	Total for fields after Jan. 1, 1937[39]		144,335	564,994,000	77,581,000		5,526	1,236	13,057	1,031	181
670	Total for Illinois[39]		258,575	1,021,888,000	82,256,000		7,951	1,250	33,858	1,070	608

[39] Total from U. S. Bureau of Mines monthly report.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg. End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
617	0	2	0											A	MisL	3,060
618	0	1	0	x	x		x	x	Waltersburg; MisU	S	P	2,260	20			
619	0	0	0	x	x		x	x	Tar Springs; MisU	S	P	2,355	16			
620	0	1	0	x	x		x	x	Bethel; MisU	S	P	2,820	10			
621	0	0	0	x	x		38.0	x	McClosky; MisL	L	P	3,010	8			
622	0	22	0											A	MisL	2,900
623	0	4	0	x	x		36.4	0.27	Tar Springs; MisU	S	P	2,115	10			
624	0	1	0	x	x		38.0	x	Hardinsburg; MisU	S	P	2,245	5			
625	0	7	0	x	x		38.0	x	Cypress; MisU	S	P	2,435	12			
626	0	5	0	x	x		39.0	x	Aux Vases; MisU	S	P	2,715	15			
627	0	1	0	x	x		38.0	x	McClosky; MisL	L	P	2,845	5			
628	0	4	0						[26]							
629	0	84	0											A	Dev	5,350
630	0	1	0	x	x		x	x	Pen	S	P	795	12			
631	0	7	0	x	x		36.0	0.22	Pen	S	P	1,475	12			
632	0	4	0	x	x		x	x	Degonia; MisU	S	P	1,995	10			
633	0	2	0	x	x		36.0	x	Clore; MisU	S	P	2,020	8			
634	0	2	0	x	x		36.0	x	Palestine; MisU	S	P	2,050	8			
635	0	36	0	x	x		36.0	x	Tar Springs; MisU	S	P	2,295	30			
636				x	x		x	x	Cypress; MisU[25]	S	P	2,720	12			
637	0	6	0	x	x		x	x	Bethel; MisU	S	P	2,810	15			
638	0	2	0	x	x		39.4	x	Aux Vases; MisU	S	P	2,940	8			
639				x	x		x	x	Levias; MisL[25]	L	P	3,015	8			
640	0	3	0	x	x		x	x	Rosiclare; MisL	S	P	3,030	6			
641	0	9	0	x	x		38.2	0.21	McClosky; MisL	L	P	3,040	9			
642	0	12	0						[26]							
643	0	45	0											A	MisL	3,150
644	0	2	0	x	x		x	x	Tar Springs; MisU	S	P	2,270	15			
645	0	1	0	x	x		x	x	Cypress; MisU	S	P	2,665	15			
646	0	7	0	x	x		x	x	Paint Creek; MisU	S	P	2,760	27			
647	0	11	0	x	x		x	x	Bethel, MisU	S	P	2,813	8			
648	0	5	0	x	x		x	x	Aux Vases; MisU	S	P	2,890	14			
649	0	1	0	x	x		x	x	Levias; MisL	L	P	3,035	5			
650	0	12	0	x	x		35.8	0.26	McClosky; MisL	L	P	3,075	12			
651	0	6	0						[26]							
652	0	146	0											A	MisL	3,080
653	0	142	0	x	x		32.1	0.28	Waltersburg; MisU	S	P	2,235	18			
654	0	1	0	x	x		x	x	Cypress; MisU	S	P	2,655	10			
655	0	3	0	x	x		x	x	Paint Creek; MisU	S	P	2,805	14			
656	0	138	0											A	Dev	5,225
657	0	66	0	x	x		31.7	0.25	Waltersburg; MisU	S	P	2,160	15			
658	0	4	0	x	x		32.0	x	Tar Springs; MisU	S	P	2,230	12			
659	0	4	0	x	x		x	x	Cypress; MisU	S	P	2,550	17			
660				x	x		x	x	Paint Creek; MisU[25]	S	P	2,750	12			
661	0	14	0	x	x		39.0	x	Bethel; MisU	S	P	2,760	17			
662	0	18	0	x	x		x	x	Aux Vases; MisU	S	P	2,880	18			
663	0	2	0	x	x		x	x	McClosky; MisL	L	P	2,995	10			
664	0	30	0						[26]							
665	0	112	0											A	MisL	3,445
666	0	90	0	x	x		39.8	0.14	Aux Vases; MisU	S	P	3,220	20			
667	0	21	0	x	x		38.0	0.16	McClosky; MisL	L	P	3,315	14			
668	0	1	0						[26]							
669	186	12,159	63													
670	186	29,650	72													

TABLE 2.—*Important Wells Drilled in Illinois in 1943*

Line Number	Pool	County	Company and Farm	Location	Total Depth, Ft.	Depth to Top, Ft.	Producing Formation	Initial Production, Bbl.[a]	Date of Completion of Discovery Well	Number of Wells Producing in Field Jan. 4, 1944
	A—DISCOVERY WELLS OF NEW FIELDS									
1	Albion East	Edwards	Mabee Oil and Gas, Cowling 1	SW NE SW 20-2S-14W	3,038	2,991	Aux Vases ss.	180	8-10-43	7
2	Belle Rive	Jefferson	Mohawk Drill. Co., Waters et al. 1	C NE NE 27-3S-4E	3,089	3,078	McClosky ls.	366	1-12-43	5
3	Beman[b]	Lawrence	Bauer, Ark Trust 1	NW NE NW 24-3N-11W	1,843	1,837	McClosky ls.	8 + 20	10- 6-42	1
4	Bennington	Wayne, Edwards	Burr Lambert, Van Schoick 1	NW SE NW 18-1N-10E	3,172	3,131	Aux Vases ss.	129	2- 9-43	2
5	Bessie	Franklin	Ohio Oil, U. S. Coal and Coke 1	NE NE NW 13-6S-3E	3,459	3,020	Levias ls.	80 + 44	6- 8-43	1
6	Bogota	Jasper	Big Chief Drill., Heap 1	C SE SE SW 28-6N-9E	3,213	3,109	McClosky ls.	152	8-17-43	6
7	Browns	Edwards	Superior, Lipper 1	NW NE SW, 28-1S-14W	3,091	2,692	Cypress ss.	209 + 34	11-23-43	1
8	Browns South	Edwards	Superior, Jack 1	SE SW SE 5-2S-14W	3,142	2,836	Bethel ss.	16 + 34	11-23-43	1
9	Calvin North	White	N. V. Duncan, Metcalf 1	SW SW NE 31-3S-14W	2,828	2,817	Bethel ss.	70	2-16-43	23
10	Covington South	Wayne	Deep Rock Oil, Atkinson et al. 1A	C NE SW 12-2S-6E	3,365	3,315	McClosky ls.	223 + 14	1-12-43	7
11	Divide	Jefferson	Bell Bros., Indiana Nat. Bank 1	E/2 NE NE 24-1S-3E	2,881	2,723	McClosky ls.	264	10-19-43	3
12	Ellery South	Edwards	Deep Oil Co., Sutton 1	S/2 NW SW 33-2S-10E	3,352	3,303	McClosky ls.	416 (Flo.)	9-14-43	2
13	Exchange	Marion	Gulf, Floyd 1	SE SE NW 25-1N-3E	2,763	2,734	McClosky ls.	155 + 14	9-14-43	2
14	Gossett	White	Smokey, Delap 1	SE SW NE 8-7S-8E	3,086	3,080	McClosky ls.	14	10-26-43	1
15	Hill	Effingham	Williams, Bushue 1	SW NW 16-6N-6E	2,653	2,571	McClosky ls.	245 + 25	10- 5-43	2
16	Johnsonville North	Wayne	Texas Co., Hoffee 1	NE NE NE 9-1N-6E	3,322	3,192; 3,252	Levias ls.,; McClosky ls.	140	11-23-43	1
17	La Clede	Fayette	Central Pipe Line, Littleton 1	NE SW 22-5N-4E	2,359	2,336	Bethel ss.	27 + 63	11-23-43	1
18	Lancaster West	Wabash, Edwards	First Nat. Petr. Trust, E. Myers 1	NE NW NW 11-1N-14W	2,873	2,857	Levias ls.	961 (Flo.)	7-27-43	2
19	Maplegrove	Edwards	Ill. Prod. Corp., Barber 1	E/2 NE SW 4-1N-10E	3,301	3,271	McClosky ls.	83	6-29-43	14
20	Marine	Madison	Rockhill Oil, L. Mayer 1	SE NW SW 15-4N-6W	2,590	1,745	Silurian	14 + 3	7-20-43	4
21	Markham City North	Jefferson	Williams et al., Dalton Comm. 1	SE SW 13-2S-4E	3,132	3,113	McClosky ls.	517	9-28-43	7
22	Mt. Auburn	Christian	W. Marlow et al., C. Ralph 1	S/2 NE NE 27-15N-2W	1,905	1,900	Silurian ls.	22	3-23-43	1
23	Mt. Vernon	Jefferson	Magnolia Petr., Newall-Badgett 1	SW NE NE 18-3S-3E	2,693	2,684	Aux Vases ss.	60 + 19	8- 3-43	5
24	Nason	Jefferson	Murchison, Sledge 1	SE SE SE 34-3S-2E	2,805	2,766	Rosiclare ss.	33	12-17-43	1
25	Parkersburg West	Edwards, Richland	Martin, Boyd 1	S/2 SE SW 26-2N-10E	3,257	3,252	McClosky ls.	340	9-21-43	2
26	Patton West	Wabash	Shell, Thrapp 1	SW SW NW 29-1N-12W	2,411	2,326; 2,358	Rosiclare ss.; McClosky ls.	207 + 121	8- 3-43	4
27	Toliver East	Clay	Obering, McGee 1	NE NE SW 30-5N-7E	2,847	2,838	McClosky ls.	300	9- 7-43	1
28	Waltonville	Jefferson	Byars & Ellison, Jefferson O. & G. 1	SE SW NW 32-3S-2E	2,766	2,466	Bethel ss.	38 + 40	5- 2-43	1
29	West Frankfort South	Franklin	E. S. Adkins, Browns Estate 1	SE NE NW 25-7S-2E	2,875	2,765	Levias ls.	182	4- 6-43	8

[a] Oil and water (pumping unless otherwise indicated).
[b] Discovered in 1942; named 4-29-43.

The average initial production of the discovery wells of the 28 new fields was 194 bbl. of oil and 15 bbl. of salt water. By comparison, the average initial production of the discovery wells of the 40 new fields of the previous year was 130 bbl. of oil and 23 bbl. of salt water.

In fields discovered since 1936, the total number of wells producing at the end of 1943 was 12,408, which may be compared with 11,404 wells producing at the end of 1942.

PRODUCTIVE ACREAGE

The area proved for production in the new fields (discovered since 1936) increased from 121,430 acres at the beginning of 1943 to 144,335 acres at the end of the year (Table 1), an increase of 22,905 acres, of which 2690 acres are in fields discovered during the current year and 20,215 in extensions to pools drilled earlier. In 1942, for comparison, 22,247 acres were added, 4540 by fields discovered during that year and 17,707 by extensions to older fields.

DRILLING

During the past year 1813 wells were completed. Of these, 1791 were oil or gas producers and dry holes and the other 22 were gas-input wells, salt-water disposal wells, and stratigraphic tests. Of the 1791 wells drilled for oil or gas, 1061 were oil wells, 9 were gas wells, and 721 were dry holes. The producers made up 59 per cent of the wells drilled. Of the total number drilled, 462 are classified as wildcat, and of these 94 were successful in obtaining production. In 1942, for comparison, producers made up 58.5 per cent of the wells drilled. Of the total number of wells drilled during that year, 549 were classified as wildcats, of which 88 were successful in obtaining production (Table 2, *A* and *B*). Important dry wildcat wells completed in 1943 are listed in Table 2*D*. A summary of drilling by counties is given in Table 5.

EXPLORATION METHODS

The results of an investigation to ascertain the reasons for the locations of the wildcat wells are set forth in Table 4. Of the 461 wildcat wells, the 413 known to have been located by scientific methods were 22 per cent successful. The 549 wells drilled in 1942, the locations of which were made by scientific methods, were 19 per cent successful. The total footage of wildcat wells drilled in 1943 was 596,204 ft., of which a total of 82,725 ft. was drilled in successful wells.

Subsurface geology and geophysics, largely the reflection seismograph, were the methods used in locating approximately 77 per cent of the wildcat wells drilled in Illinois. The methods of locating the 28 wells that discovered new pools in Illinois were as follows: Subsurface geology, 14; seismograph surveys, 9; combination of seismograph and subsurface geology, 3; combination of gravimeter and seismograph, one; subsurface geology and gravimeter, one. The number of seismograph parties operating throughout the year was as follows:

Jan.	11	July	6
Feb.	11	Aug.	5
Mar.	10	Sept.	5
Apr.	8	Oct.	5
May	7	Nov.	6
June	6	Dec.	5

Calculated in party-months, the amount of seismograph work done in Illinois in 1943 was only about half that done in 1942.

DEEP TESTS DURING 1943

Few deep tests were drilled in Illinois in 1943 (see Table 2). There was one discovery of Devonian limestone production in pools producing from shallower formations; namely, in the Patoka pool (Table 2*C*, line 39). Two new pools were discovered in the Silurian—the Mt. Auburn pool,

TABLE 2.—(*Continued*)

Line Number	Pool	County	Company and Farm	Location	Total Depth, Ft.	Depth to Top, Ft.	Producing Formation	Initial Production, Bbl.[a]	Date of Completion of Discovery Well
B—DISCOVERY WELLS OF EXTENSIONS TO POOLS									
1	Akin	Franklin	Seaboard, U. S. Coal & Coke 8	C NE NE 26-6S-4E	3,132	3,122	Aux Vases ss.	275 + 3	3-23-43
2	Akin	Franklin	Lario O. & G., Franklin Co. Mining 1	SW SW NW 36-6S-4E	3,156	3,122	Aux Vases ss.	46 + 12	5-18-43
3	Albion	Edwards	First Nat. Petr., Brown 1	S/2 SW SW 6-2S-11E	3,030	3,008	Aux Vases ss.	158	10-19-43
4	Albion	Edwards	Superior Oil, Earhart 1	NW SE SE 25-2S-10E	3,233	2,416; 3,170	Waltersburg ss.; McClosky ls.	152 + 65	10-26-43
5	Albion	Edwards	Noah, Edwards County Poor Farm 1	NE SW NW 6-2S-11E	3,161	3,102	Levias ls.	41 + 10	11-30-43
6	Albion	Edwards	Lewis Prod., Dunk 2	NW SE SE 36-2S-10E	2,422	2,388	Waltersburg ss.	184	11- 9-43
7	Albion East	Edwards	Superior, Bender 1	SW NE NW 29-2S-14W	3,179	3,139	Weiler ss.; Aux Vases ss.; McClosky ls.	131 + 15	12- 7-43
8	Albion East	Edwards	Superior, Reid 1	SW NE NE 29-2S-14W	3,233	2,783	Cypress ss.	34 + 55	11- 2-43
9	Barnhill East	Wayne	Cities Service, Perry 1	SW/4 28-2S-9E	3,378	3,283	Levias ls.; Rosiclare ss.	174	10- 5-43
10	Barnhill East	Wayne	Cities Service, Vaught 1	W/2 SW NW 33-2S-9E	3,302	3,290	McClosky ls.	209	9- 7-43
11	Barnhill East	Wayne	Nat. Refining Co., P. Hill 1	NW SW SE 29-2S-9E	3,293	3,281	McClosky ls.	191	2- 9-43
12	Bennington	Wayne	Schoonmaker et al., Fitch 1	SE SW SE 12-1N-9E	3,349	3,149	Aux Vases ss.	15	6- 1-43
13	Blairsville	Hamilton	Magnolia, R. Odell 1	E/2 NE SE 17-4S-7E	3,490	3,338	Levias ls.	17 + 25	4-27-43
14	Boyleston	Wayne	Pure, Porter 1	C NW SW 23-1S-7E	3,275	3,266	McClosky ls.	12 + 24	8-17-43
15	Bungay	Hamilton	Ohio, York 1	SW SW SW 26-4S-7E	3,320	3,298	Aux Vases ss.	452 (Flo.)	10-12-43
16	Calvin	White	Whisenant & Trenchard, E. E. Owens 1	SW NW NW 18-4S-14W	2,853	2,800	Bethel ss.	65	7-13-43
17	Calvin North	White	British-American Oil, F. Metcalf 1	SW SE NE 31-3S-14W	1,540	1,526	Pennsylvanian ss.	125	7-20-43
18	Calvin North	White	Slaghter Partier, Sefried 1A	NW SE SW 30-3S-11E	2,400	1,850	Biehl ss.	44 + 11	11- 9-43
19	Clay City Consold	Wayne	Robinson Puckett, Gordon Mulhback 1	NE SW NE 1-1N-8E	3,120	3,085	Rosiclare ss.	127	12- 7-43
20	Clay City Consold.	Wayne	Pure, Gray "A" 1	NW NW SE 34-2N-7E	2,998	2,978	Aux Vases ss.	125	10-19-43
21	Clay City Consold.	Wayne	Washburn & Powers, Jordan 1	SE NW 34-2N-7E	2,977	2,968	Aux Vases ss.	230	10-19-43
22	Clay City Consold	Wayne	Rockhill & Pure, Riggs 1	C NE NE 22-1N-8E	3,145	3,023	Levias ls.	6 + 2	7- 6-43
23	Coil West	Jefferson	Gulf, McMail 1	NW SE NE 23-1S-4E	2,901	2,882	McClosky ls.	494	9-28-43
24	Concord	White	Great Lakes Carbon, Reiling 1	SW SE SE 21-6S-10E	3,115		McClosky ls.	159	12- 7-43
25	Covington	Wayne	Buren & McGregor, Fee 1	C NW SE 32-1S-7E	3,281	3,274	McClosky ls.	50	8- 3-43
26	Covington South	Wayne	Ohio Fuel Supply, Mussbaum 1	C NW SW 13-2S-6E	3,335	3,308	McClosky ls.	375 + 16	7-13-43
27	Dale-Hoodville	Hamilton	H. Gussman, Mead 1	SE SE NW 23-5S-6E	3,222	3,105	Levias ls.	143 + 37	5-18-43
28	Dundas Consolidated	Jasper	F. Jablonski, S. Brown 1	E/2 SW SE 12-5N-9E	2,980	2,954	McClosky ls.	20 + 14	6-22-43
29	Friendsville	Wabash	Skiles, Murray et al. 1	SE SE SE 34-1N-13W	1,805	1,781	Palestine ss.	70 + 15	3-23-43
30	Grayville	White	Skiles Partee, Hoerner 1	E/2 NW NE 25-3S-10E	3,182	2,921	Bethel ss.	65	11-23-43
31	Grayville West	Edwards	Midstates Oil & Ashland Ref., Coad 1	NW NW NW 13-3S-10E	3,240	1,977	Pennsylvanian ss.	15 + 22	7-27-43
32	Herald	White	W. C. McBride, Bailey 1	SW SW SE 3-7S-9E	3,125	2,684	Cypress ss.	62 + 7	6- 1-43
33	Ina	Jefferson	Nash Redwine, Gilbert 1	NE SE NW 25-4S-2E	3,050	2,999	St. Louis ls.	10	8-17-43
34	Ingraham	Clay	Sinclair-Wyoming, A. Hinterscher 1	C NE SE 4-4N-8E	3,054	3,013	McClosky ls.	42 + 90	8-31-43
35	Ingraham	Clay	Superior, Hinterscher 1	NE SE NW 11-4N-8E	3,148	3,063	McClosky ls.	15	9-28-43
36	Iola	Clay	H. S. Williams, McGee 1	NW NW SE 22-5N-5E	2,358	2,350	Aux Vases ss.	158	8-31-43
37	Iola	Clay	Texas, N. Birch 1	SE SE NE 16-5N-5E	2,367	2,354	Aux Vases ss.	60 + 5	2-16-43
38	Iola	Clay	L. Waggoner, Pilcher 1	C SW NW 13-5N-5E	2,466	2,452	McClosky ls.	699 (P. & Flo.)	6-15-43
39	Johnsonville West	Wayne	Wisconsin Oil & Ref., Powless 1	C NE SW 13-1N-5E	3,131	2,985	Aux Vases ss.	36	7- 6-43
40	King	Jefferson	Seaboard, Eldridge Community 1	NE SE NE 3-4S-3E	2,907	2,892	Rosiclare ss.	53 + 8	5-11-43
41	Maplegrove	Edwards	Ryan & Fortner, Ralston 1	E/2 SW SE 9-1N-10E	3,340	3,271	McClosky ls.	758 (Flo.)	8-10-43
42	Maplegrove	Edwards	Ryan & Fortner, Moats 1	E/2 NW NE 9-1N-10E	3,259	3,249	McClosky ls.	996	9-21-43
43	Marine	Madison	Eason-Rockhill, Pence 1	SE NE NE 16-4N-6W	1,767	1,705	Silurian	168 + 103	10-19-43

44	Mattoon	Coles	A. F. Keating, F. Uphoff 1	SE NW NW 25-12N-7E	2,063	2,012	Aux Vases ss.	25 + 24	7-20-43
45	Maunie North	White	Skelly, Ramming 1	SW SW NE 24-5S-10E	3,120	3,007	McClosky ls.	7 + 30	10-12-43
46	Mill Shoals	Wayne	Shulman, Poorman 1	SW SW 18-3S-8E	3,423	3,235	Aux Vases ss.	44 + 18	12- 7-43
47	Mt. Carmel	Wabash	Superior, Vehman 1	NW SW NW 9-1S-12W	2,403	1,504; 2,164	Biehl ss.; Bethel ss.	126	5-11-43
48	Mt. Carmel	Wabash	George & Wrather, Dunkel 1	SW SW NW 4-1S-12W	2,347	1,985	Weiler ss.	3 + 5	7- 6-43
49	Mt. Carmel	Wabash	Yingling, Shaw 1	NE NE SE 7-1S-12W	2,431	2,058	Cypress ss.	208 F.	8-24-43
50	Mt. Carmel West	Wabash	Dean & Morton, B. Townsend 1	NE NE SW 14-1S-13W	2,263	1,881	Waltersburg ss.	40	2- 2-43
51	Mt. Erie	Wayne	L. Romaine, Kinney 1	NE SE NE 16-1S-8E	3,144	3,124	Aux Vases ss.	22	3- 9-43
52	Mt. Erie South	Wayne	H. H. Weinert, McConnell 1	C NE NW 27-1S-8E	3,252	3,119	Aux Vases ss.	88	7-27-43
53	Mt. Vernon	Jefferson	Redwine, Casey 1	NE SW NE 6-3S-3E	2,808	2,801	McClosky ls.	280	11- 2-43
54	Noble	Richland	Pure, Rusk "A" 1	C SW SE 19-3N-9E	3,055	2,987	McClosky ls.	118	8-17-43
55	Patton West	Wabash	Shell, Risley 1	SW/4 29-1N-12W	2,388	2,331	Rosiclare ss	4 + 4	11-30-43
56	Phillipstown	White	Phillips Petr., Kuykendall 1	N/2 NE NE 25-4S-10E	3,091	3,076	McClosky ls.	45 + 60	1-12-43
57	Phillipstown	White	Sun and Pure, Luts 1	SE SW NW 30-4S-14W	3,108	3,035	McClosky ls.	68	5-23-43
58	Phillipstown	White	Kubat, E. W. Johnson 1	NW SW NW 19-4S-11E	3,120	1,981	Degonia ss.	35 + 65	6-29-43
59	Phillipstown	White	Eason Oil, Clark 1	SE NW NW 30-4S-11E	1,346	1,333	Pennsylvanian ss.	231	7- 6-43
60	Rural Hill	Hamilton	Bailey-Benson, Oglesby 1	NW NE SW 17-6S-6E	3,141	3,127	Aux Vases ss.	60	12-21-43
61	Schnell	Richland	Pure, A. N. Earnst 1	E/2 NW NW 31-3N-9E	3,005	2,990	McClosky ls.	98	2-23-43
62	Schnell	Richland	Pure, Hoat 1	S/2 SW/4 30-3N-9E	3,075	2,973	McClosky ls.	138	10-26-43
63	Sims North	Wayne	Pure Oil, A. Spicer 1	C SE SW 8-1S-6E	3,235	3,009	Aux Vases ss.	351	1-12-43
64	West Frankfort South	Franklin	E. S. Adkins, Biggs "S" 1	SE SE NE 25-7S-2E	2,096	2,026	Tar Springs ss.	119	6-22-43
65	West Frankfort South	Franklin	Adkins, Sharkey 1-T	NW SW NE 30-7S-3E	2,975	2,740	Levias ss.	97 + 4	12-21-43
66	Whittington	Franklin	Nash Redwine, Taylor 1	SE SW NW 21-5S-3E	3,115	2,538	Cypress ss.	199	11-16-43

C—Discovery Wells of Additional Producing Zones in Pools

1	Aden	Wayne	Texas, Silverman 6	16-3S - 7E	3,297	3,292	Levias ls.	194	9-28-43
2	Aden	Wayne	Texas, Goudy 3	16-3S - 7E	3,375	3,319	Rosiclare ss.	320 + 8[c]	10- 5-43
3	Aden North	Wayne	Texas, Gernon 1	33-2S - 7E	3,343	3,200	Aux Vases ss.	164 + 2	9-14-43
4	Akin	Franklin	Lario, Franklin Co. 2	36-6S - 4E	3,282	3,271	McClosky ls.	76	8-17-43
5	Albion	Edwards	Noah, Edwards County Poor Farm 1	6-2S -11E	3,161	3,102	Levias ls.	41 + 10	11-30-43
6	Albion East	Edwards	Kingwood, W. Cowling 1	20-2S -14W	3,247	3,090	Levias ls.	172	8-31-43
7	Barnhill	Wayne	Robinson, Oakly "A" 3	34-2S - 8E	3,396	3,225	Aux Vases ss.	20 + 5	8-10-43
8	Barnhill East	Wayne	Cities Service, Perry 1	28-2S - 9E	3,378	3,283	Levias ls.	174 F.	10- 5-43
9	Blairsville	Hamilton	Texas, Drew Comm. 2	20-4S - 7E	3,374	3,367	Rosiclare ss.	428 F + 24 W	10-14-43
10	Boyleston	Wayne	Watkins, Furguson 1	3-2S - 7E	3,270	3,090	Aux Vases ss.	110	5- 4-43
11	Calvin North	White	McBride, Hon et al. 1A	6-4S -14W	2,347	2,330	Tar Springs ss	81	4-20-43
12	Calvin North	White	McBride, Potter 1	6-4S -14W	2,301	2,254	Waltersburg ss.	190	7-20-43
13	Calvin North	White	McBride, A. Hon 1	6-4S -14W	2,158	1,997	Palestine ss.	50 + 24	8-10-43
14	Calvin North	White	Duncan, Hon 3	6-4S -14W	1,609	1,503	Pennsylvanian ss.	134	5-18-43
15	Calvin North	White	Duncan, B. Metcalf 2	31-3S -14W	2,896	2,877	Aux Vases ss.	36	6- 1-43
16	Concord	White	Wise & Sohio, Meyer 1	28-6S -10E	3,053	2,932	Levias ls.	210	11-23-43
17	Concord	White	Great Lakes Carbon Corp., White County Bank 1	28-6S -10E	2,290	2,271	Tar Springs ss.	89 + 40	12- 7-43
18	Dale-Hoodville	Hamilton	Pure, Johnson Consol. 1	18-6S - 7E	2,435	2,429	Tar Springs ss.	1,187 F.	7-13-43
19	Friendsville	Wabash	Bailor, Michael 1A	27-1N-13W	2,667	2,647	Levias & McClosky ls.	35 + 5	7-13-43
20	Friendsville	Wabash	Baylor, Beamon 1A	27-1N-13W	2,659	2,624	Levias ls.	125	9-14-43
21	Herald	White	McBride, Aud 1	3-7S - 9E	2,946	2,919	Aux Vases ss.	20 + 10	8-10-43
22	Inman East	Gallatin	Cherry & Kidd, Wright 2	15-8S -10E	2,396	2,137	Hardinsburg ss.	200 + 4	10-19-43
23	Inman West	Gallatin	Green, Grant 1	15-8S - 9E	2,219	2,174	Tar Springs ss	17	3- 9-43
24	Inman West	Gallatin	Globe & R. B. Martin, Straub 1	22-8S - 9E	2,928	2,877	McClosky ls.	19 + 13	5-18-43
25	Iola	Clay	Luttrell, Reed Heirs 1	15-5N- 5E	2,306	2,240	Paint Creek Stray ss.	80 + 10	2-16-43
26	Iola	Clay	Luttrell, Reed Heirs 5	15-5N- 5E	2,154	2,125	Weiler ss.	195	2- 2-43
27	Iola	Clay	Texas, Kidwell 5	15-5N- 5E	2,437	2,427	McClosky ls.	385	2-16-43

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[c] Oil + water.

TABLE 2.—(*Continued*)

Line Number	Pool	County	Company and Farm	Location	Total Depth, Ft.	Depth to Top, Ft.	Producing Formation	Initial Production, Bbls.[a]	Date of Completion
28	Johnsonville W.	Wayne	Wisconsin Oil & Ref., Powless 1	13-1N- 5E	3,131	2,971	Aux Vases ss.	36	7- 6-43
29	Kenner	Clay	Williams, Green 4	30-3N- 6E	2,845	2,812	Aux Vases ss.	23 + 3 s.w.	10-12-43
30	Lancaster West	Wabash	Bennett Bros., Hinterliter et al. 1	11-1N-14W	2,863	2,851	Rosiclare ss.	52 F.	8-24-43
31	Mason South	Effingham	Braun, Trimble 1	26-6N- 5E	2,441	2,433	Rosiclare ss.	65	4- 6-43
32	Maunie	White	B. B. & M. Drill., Barns 1	12-6S -10E	1,328	1,306	Bridgeport ss.	22	11-23-43
33	Maunie North	White	Continental, Ackerman 2	25-5S -10E	2,961	2,930	Aux Vases ss.	117	10-12-43
34	Mt. Erie South	Wayne	Bell Bros., Borah 1	22-1S - 8E	3,142	3,120 ±	Levias ls.	255	8-31-43
35	Mt. Erie South	Wayne	Pure Oil, J. Creighton 1	22-1S - 8E	3,097	3,072	Aux Vases ss.	135	8-31-43
36	McKinley	Washington	DeKalb, Hunleth 1	30-3S - 4W	1,220	1,015	Bethel ss.	46	8-31-43
37	Mt. Vernon	Jefferson	Gulf, Hull 1	6-3S - 3E	2,845	2,752	Levias ls.	16 + 50	12-28-43
						2,833	McClosky ls.		
38	Olney	Richland	Texas, Boatman Comm. 1	27-4N-10E	3,094	3,063	Levias ls.	90	7-27-43
39	Patoka	Marion	Adams O. & G., Pugh 10-D	29-4N- 1E	2,908	2,837	Devonian ls.	103 + 7	2- 9-43
40	Phillipstown	White	Sun Oil, Garner 9	6-5S -11E	2,356	793	Pennsylvanian ss.	150	1-19-43
41	Phillipstown	White	Jarvis & Marcell, Garner 5	31-4S -11E	1,544	1,473	Pennsylvanian ss.	80 + 65	4- 6-43
42	Phillipstown	White	Eason, Clark 2	30-4S -11E	3,116	2,808	Bethel ss.	119	8-10-43
43	Phillipstown	White	Phillips Petr., Laura 4	19-4S -11E	3,043	3,016	Levias ls.	58	11- 9-43
44	Phillipstown	White	Tide Water, Dennis "B" 2	18-4S -11E	3,005	2,001	Degonia ls.	18 + 30	12- 7-43
						2,722	Cypress ss.		
45	Sailor Springs	Clay	McBride, Hancock 1	10-3N- 7E	2,620	2,390	Glen Dean ls.	91 + 3	1-26-43
46	Sims North	Wayne	Texas, Talbert 6	17-1S - 6E	3,174	3,082	Levias ls.	306	6-22-43
47	Stokes	White	Pure, Pyle Consold. 4	18-6S - 9E	2,960	2,664	Weiler ss.	30	1-19-43
48	Stokes	White	Pure & Carter, Goudy Consol. 1	7-6S - 9E	3,045	3,033	Levias ls.	157	6- 8-43
49	Woodlawn	Jefferson	Magnolia, Shirley 7	35-2S - 1E	1,961	1,780	Cypress ss.	108 + 8	8- 3-43

Christian County, and the Marine pool, Madison County (Table 2*A*, lines 20, 22). The deepest formations reached in 61 important dry tests are indicated in Table 1. The considerable number of "Trenton" tests in Madison, St. Clair and adjacent counties followed the discovery in 1942 of "Trenton" production in the St. Jacob pool, Madison county.

Only four of the tests listed in Table 2*D* reached the St. Peter sandstone (lines 16, 18, 19 and 47) and one reached the Eau Claire in the Cambrian (line 16).

Development

Most of the new discoveries and development during 1943 took place in White, Wayne, Wabash, Clay, Jefferson, and Hamilton counties in the southeastern part of the state. In Wayne County 228 wells were drilled, of which 151 were producing wells (Table 5). Some of the fields in which the greatest number of producing wells were drilled in 1943 are the Mt. Carmel (Wabash County), Clay City Consolidated (Clay and Wayne Counties), Phillipstown Consolidated (White County), Bible Grove (Clay and Effingham Counties), Iola (Clay County), and Dale-Hoodville Consolidated (Hamilton County) fields.

Prospects for 1944

The outlook for 1944 is for drilling to continue at nearly the same rate as in 1943, with a gradual decline unless there is a major discovery, a rise in the price of crude oil, or a modification of well-spacing restrictions accompanied by adequate supplies of material and manpower.

Economic Data

On the basis of posted prices, the total value of the oil produced in 1943 was approximately $111,989,470. Posted prices for Illinois crude oil in 1943 were $1.37 for the central basin fields, Salem area, and Griffin area, and $1.22 per barrel for oil in the old fields.

In 1943, a total of 4,611,695 ft. of hole was drilled in the state. Of this amount 2,766,912 ft. represents producing wells. With an assumed average cost of $3.50 per foot, the total investment in drilling was $16,140,932.50, including both producing wells and dry holes. In the 461 wildcats completed during the year, 1,189,317 ft. of hole was drilled. At $3.50 per foot, the drilling cost of these wildcats amounted to $3,762,609.50. The average depth of all wells drilled in the state in 1943 was 2573 ft., as compared with 2607 ft. in 1942.

The average initial production of the oil wells for 1943 was 123 bbl. as against 182 bbl. for 1942.

Pipe Lines

There was little construction of trunk pipe lines to serve Illinois oil fields or Illinois refineries during 1943. As shown by the detailed statement below, construction was largely confined to loops and short spurs.

Construction by the War Emergency Pipe Line Inc. in Illinois continued in 1943. The "Big Inch" crude-oil line (24-in.) from Longview, Texas, started transporting oil to Norris City, Ill., in January 1943, and in August 1943 it started transporting oil from Norris City to the East. The "Little Big Inch" (20-in.) products line from Beaumont, Texas, which parallels the "Big Inch" across Illinois, was under construction during 1943 and was reported to be nearly completed by the end of the year.

Crude Oil

Magnolia Pipe Line Co.—2 miles 3-in., Woburn field to 8-in. line of the Ohio Oil Co., Bond County; 3 miles 2-in., Beaver Creek field to 10-in., Magnolia pipe line (formerly Socony-Vacuum), Bond County.

TABLE 2.—(*Continued*)

Line Number	County	Location	Company and Farm	Total Depth	Deepest Formation	Depth to Top, Ft.	Date Completed
			D IMPORTANT DRY TESTS				
1	Bond	29-5N-4W	Aetna Oil, M. Spengel 1	3,000	"Trenton"	2,941	7-27-43
2	Bond	14-6N-2W	E. Burgard, Klaus 1	2,460	Devonian	2,425	3- 2-43
3	Champaign	1-22N-7E	R. F. G. Drill., Reynolds 3	324	Silurian		6- 1-43
4	Christian	26-15N-2W	Wainright, Bernard 1	2,000	Devonian	1,926	8-31-43
5	Clinton	7-1S-5W	Smokey Oil, J. Friedrich 1	2,741	"Trenton"	2,698	1-26-43
6	Clinton	3-2N-4W	Eason Oil, Schuette 1	3,171	"Trenton"	3,102	3- 2-43
7	Clinton	15-1N-4W	Derby Oil, Conrad Houkap 1	3,287	"Trenton"	3,249	3- 9-43
8	Clinton	22-1N-2W	Wiser Oil, M. Wessel 1	2,815	Devonian	2,700	7- 6-43
9	Clinton	22-2N-1W	Black and Pearson, H. Kluth 1	3,028	Devonian	2,916	7-13-43
10	Clinton	29-3N-2W	P. Mosebach, M. B. Skidmore 1	2,679	Devonian	2,571	9- 7-43
11	Coles	35-14N-7E	Continental, Minno Daily 1	3,172	Devonian	2,940	6-29-43
12	Crawford	11-8N-12W	Ryan Oil (Powers-Krohn), Boyer 1	2,899	Devonian	2,590	12- 7-43
13	Douglas	31-15N-10E	S. J. Burkett, W. L. Worley 1	1,216	Silurian	1,178	8-17-43
14	Edgar	1-13N-14W	Tom Poppasetal, J. O. Halland 1	2,212	"Trenton"	2,165	6-22-43
15	Fayette	28-9N-1E	Northern Ordnance, Inc., M. O'Conner 1-D	3,140	Devonian	2,987	4-20-43
16	Ford	19-24N-7E	Nelson, Urp, Stroh, J. Urp 1	3,955	Eau Claire	3,805	7-20-43
17	Ford	1-28N-9E	A. C. Murray, Paulsen 1	720	"Trenton"	690	1- 4-44
18	Fulton	17-6N-1E	J. L. Smith, Bradley 1	1,130	St. Peter	1,116	8- 3-43
19	Greene	30-11N-13W	D. S. Brooks, Valley Farms 2	765	St. Peter	756	5-25-43
20	Hancock	20-3N-5W	Dale Hopkins, K. H. Slater 1	673	Devonian	620	11- 9-43
21	Henderson	14-9N-14W	Newhall Corp., Hanna 1	610	Maquoketa	416	3- 2-43
22	Henderson	8-8N-5W	C. D. Kidder, C. H. Carpenter 1	530	Devonian	365	4- 6-43
23	Jefferson	27-3S-3E	Nash Redwine, Prudential Life Ins. 1	4,759	Devonian	4,536	4- 6-43
24	Kankakee	2-29N-12W	Ste. Anne Petr., V. A. Cote 1	780±	"Trenton"		3- 9-43
25	Madison	11-3N-6W	C. G. Smith, Michael 1	2,548	"Trenton"	2,514	4-13-43
26	Madison	12-3N-9W	J. Kesl, Gargac 1	1,370	Devonian	1,262	1-19-43
27	Madison	21-5N-6W	R. Powers, Kaufman-Isenburg 1	2,573	"Trenton"	2,452	1-12-43
28	Madison	33-4N-7W	L. Alch, Gusewelle 1	2,370	"Trenton"	2,269	2- 9-43
29	Madison	29-5N-5W	Kingwood, J. E. Niggli 1	2,715	"Trenton"	2,618	2-23-43
30	Madison	23-3N-5W	McCollough, Blacet 1	2,948	"Trenton"	2,852	4-27-43
31	Marion	14-3N-1E	Shell Oil, Sugg Heirs 1	3,344	Devonian	3,245	2- 2-43
32	Mason	19-22N-6W	E. W. Hayes, Null 1	1,401	"Trenton"	1,289	6- 1-43
33	Monroe	13-3S-10W	Vawter & Braun, Dill 1	965	"Trenton"	904	7- 6-43
34	Montgomery	35-11N-5W	Central Pipe Line, Gees 1	2,467	"Trenton"	2,408	9-28-43
35	Montgomery	31-8N-5W	W. R. Holmes, Monke 1	752	Pottsville	600	4-13-43
36	Montgomery	28-8N-5W	W. R. Holmes, Sewing 1	699	Pennsylvanian	565	6- 8-43
37	Montgomery	32-11N-5W	Myers & Duff, Keys 1	652	Pennsylvanian		11- 2-43
38	Moultrie	13-15N-6E	Continental Oil, J. L. Beachy 1	3,681	"Trenton"	3,518	4-20-43
39	Perry	36-4S-2W	Texas, J. Matlavish 1	4,119	"Trenton"	3,984	3-23-43
40	Pike	14-5S-6W	Mineral Develop., G. S. Hyde 2	621	"Trenton"	466	9-28-43
41	Putnam	3-31N-1W	Fuller & Turner, McGhiey 1	2,000	New Richmond	1,940	8-10-43
42	Randolph	25-5S-5W	Southwestern Ill. Coal Corp., Cleland 1	2,566	Devonian	2,466	12-14-43

43	St. Clair[e]	28-1N-10W	Tarleton et al., Dryoff 1-A	1,800	New Richmond	1,614	4- 6-43
44	St. Clair	16-2N-6W	Big Four Oil & Gas, Voges 1	2,995	"Trenton"	2,494	3- 2-43
45	St. Clair	17-2S-8W	H. C. Robertson et al. Karban 1	1,480	"Trenton"	1,410	2-23-43
46	St. Clair	18-1S-6W	D. S. Hager, Klingle 1	2,363	"Trenton"	2,257	3- 9-43
47	St. Clair	4-1S-8W	Eason Oil, E. Thomas 1	2,174	St. Peter	2,157	3-30-43
48	St. Clair	24-2S-6W	J. Vetch, M. Lange 1	2,745	"Trenton"	2,632	3-30-43
49	St. Clair	24-1S-9W	N. W. Whitton, G. Grossman 1	1,505	"Trenton"	1,427	5-25-43
50	St. Clair	31-1S-8W	H. Gass, A. Englerth 1	1,605	"Trenton"	1,522	7-20-43
51	St. Clair	29-1N-6W	Eason et al., Engle 1	2,452	"Trenton"	2,346	8-31-43
52	St. Clair	32-2N-7W	W. P. Muller, Smiley 1	1,990	"Trenton"	1,946	8-24-43
53	Sangamon	15-15N-3W	Davis, Taft 1	1,850	Silurian	1,787	12-14-43
54	Sangamon	21-15N-3W	O. A. Reed et al., C. Ross 1	2,314	"Trenton"	2,217	12-28-43
55	Shelby	21-10N-4E	W. Duncan, H. H. Hoskins 1	3,236	Devonian	3,110	7-27-43
56	Shelby	18-11N-6E	Texas, Ferguson 1	3,534	Devonian	3,345	12-28-43
57	Union	35-11S-1W	Little Egypt Oil, Basler 1	4,053	"Trenton"	3,999	9-21-43
58	Warren	31-8N-1W	King & Heiser, M. Gren 1	810	Maquoketa	742	3-30-43
59	Washington	32-2S-4W	Texas, C. L. Kokesh 1	2,485	Devonian	2,339	6-22-43
60	Washington	9-1S-4W	Fisher Oil et al., J. Rossell 1	2,646	Devonian	2,340	7-20-43
61	Will	21-35N-9E	Brown & Feltis, Gardner 1	900	Platteville		6- 8-43

[d] In Warrenton, Borton pool.

[e] In Dupo pool.

Ohio Oil Co.—2 miles 14 in., Wood River station to the Allied Pipe Line Company's dock on the Mississippi River, Madison County (under construction).

Pure Oil Co.—4 miles 4-in., Geff field to the Cisne station, Wayne County; 7 miles 4-in. and 6-in., Sims North field to Johnsonville field, Wayne County; 4 miles 4-in., Schnell field to Pure Oil Co. trunk line, Richland County; 14 miles 4-in., Mt. Erie South field northeast to Mt. Erie field, then northwest to the Pure Oil Co. trunk line which runs through the Clay City Consolidated field, Wayne County.

Sohio Pipe Line Co.—14 miles, 4-in., Brownstown station of the Ohio Oil Co. pipe line to Louden field, Fayette County; 3 miles 3-in., Coil West field to Ashland Oil and Refining Co. pipe line, to the Johnsonville station, Wayne County; 5 miles 2-in., Dahlgren and Mayberry fields to the Texas pipe line to Johnsonville station, Wayne County; 12 miles 4-in., extension to Benton field line running near West Frankfort, Franklin County; 10 miles 4-in., Maplegrove field to the Parkersburg station, Edwards County; 2 miles 4-in., Stringtown field to Sohio trunk line, Richland County.

Texas Pipe Line Co.—20 miles 6-in., Woodlawn station to Salem station, Marion County; 20 miles 6-in., Hilliard station to the Clay City station, Wayne County.

NATURAL GAS

Citizens Natural Gas Co.—½ mile 2-in., Panhandle Eastern Pipe Line Co. line to Newman, Crawford County.

Natural Gas Pipe Line Company of America—1 mile 2-in., Natural Gas Pipe Line Company of America trunk line to Princeton, Bureau County.

REFINERIES

No new refineries were constructed in Illinois during 1943; however, the total daily refinery capacity was increased from 281,000 to 289,000 barrels.

During the year Illinois crude-oil production amounted to 26 per cent of the runs to stills for refineries in the Central refining district (Illinois, Indiana, Ken-

TABLE 3.—*Completions and Production in Illinois since January* 1, 1936

	Number of Completions[a]	Number of Producing Wells	Production, Thousands of Barrels		
			New Fields[b]	Old Fields[b,c]	Total[d]
1936	93	52			4,445
1937	449	292	2,884	4,542	7,426
1938	2,541	2,010	19,771	4,304	24,075
1939	3,675	2,970	90,908	4,004	94,912
1940	3,829	3,080	142,969	4,678	147,647
1941	3,838	2,925	128,993	5,145	134,138
1942	2,016	1,179	101,837	4,753	106,590
1943:					
January	135	84	7,005	396	7,401
February	142	104	6,352	368	6,720
March	137	89	6,908	434	7,342
April	157	91	6,518	396	6,914
May	111	66	6,482	380	6,862
June	115	64	6,257	423	6,680
July	181	98	6,360	396	6,756
August	144	80	6,303	388	6,691
September	135	79	6,211	381	6,592
October	196	129	6,466	376	6,838
November	138	81	6,325	374	6,699
December	200	123	6,399	362	6,761
Total	1,791	1,087[e]	77,586	4,674	82,256

[a] Includes only oil or gas producers and dry holes.
[b] Production figures based on information furnished by oil companies and pipe-line companies.
[c] Includes Devonian production at Sandoval and Bartelso.
[d] From the U. S. Bureau of Mines.
[e] Includes 22 wells formerly dry holes.

TABLE 4.—*Wildcat Wells Drilled in Illinois in* 1943

CLASSIFIED ACCORDING TO METHOD OF LOCATION

Method	Number of Wells	Number of Producers	Percentage of Wells Successful
Geology	306	70	23
Geophysics (chiefly seismograph but including gravimeter)	69	15	22
Seismograph and geology	38	6	16
Total scientific	413	91	22
Nonscientific	48	3	6
Unknown	0	0	0
Total	461	94	20

tucky, Michigan and western Ohio) and the Appalachian refining district (eastern Ohio, western New York, western Pennsylvania and West Virginia). For December 1943, the runs to stills in the Central and the Appalachian refining districts were 27,807,000 bbl. Of this amount Illinois production was 24.3 per cent. Stocks of crude petroleum on hand in Illinois on Dec. 31, 1943, were 14,053,000 bbl. as compared with 9,170,000 bbl. on Dec. 31, 1942. Stocks of refined products in the Central and Appalachian refining districts compared with the previous year according to the U. S. Bureau of Mines, are as follows:

Product	Dec. 31, 1943, Bbl.	Dec. 31, 1942, Bbl.
Gasoline	18,514,000	19,026,000
Gas, oil and distillate fuel	6,947,000	6,643,000
Residual fuel oil	3,307,000	3,025,000

NATURAL GAS

The amount of natural gas produced and marketed in Illinois during 1943 was approximately 2410 million cubic feet. The amount marketed from each field is given in Table 7.

Five new wells were drilled within proved territory in the Russellville gas field during 1943, bringing the total number of producing wells in the field to 59. All of these new wells produce from the Bridgeport sand. To the end of

1943 the productive area of the Buchanan sand proved by drilling was 1650 acres and of the Bridgeport, 270 acres. The initial productions of the wells added to the pool during 1943 were of the order of 3 million cubic feet of gas per day.

TABLE 5.—*Summary of Drilling and Initial Production in Illinois for 1943*

County	Number of Wells Drilled			Total Initial Production		Footage Drilled[a]	
	Total Completions	Total Producing		Oil, Bbl.	Gas, Millions Cu. Ft.	Total	Producing Wells
		Oil	Gas				
Adams	1	0	0	0	0	1,273	0
Bond	13	0	1	0	2.10	18,472	2,073
Brown	1	0	0	0	0	297	0
Champaign	1	0	0	0	0	324	0
Christian	4	1	0	22	0	7,152	1,905
Clark	6	2	0	20	0	4,739	903
Clay	201	148	0	16,342	0	543,900	401,218
Clinton	44	9	2	1,915	7.00	87,997	27,889
Coles	8	1	0	25	0	15,519	2,063
Crawford	7	0	0	0	0	15,631	0
Cumberland	10	0	0	0	0	22,860	0
Douglas	1	0	0	0	0	1,216	0
Edgar	1	0	0	0	0	2,212	0
Edwards	68	37	0	8,652	0	206,844	111,030
Effingham	44	29	0	1,742	0	107,071	68,339
Fayette	44	18	0	1,360	0	96,902	42,758
Ford	2	0	0	0	0	4,675	0
Franklin	58	25	0	2,254	0	158,921	67,357
Fulton	1	0	0	0	0	1,130	0
Gallatin	49	39	0	3,349	0	116,730	88,444
Greene	1	0	0	0	0	765	0
Hancock	1	0	0	0	0	673	0
Hamilton	156	112	0	19,554	0	483,779	338,906
Henderson	2	0	0	0	0	1,140	0
Jackson	2	0	0	0	0	4,684	0
Jasper	26	11	0	2,324	0	76,970	32,894
Jefferson	116	64	0	10,214	0	325,764	171,830
Kankakee	1	0	0	0	0	780	0
Lawrence	66	31	5	2,510	16.43	104,376	52,512
Livingston	1	0	0	0	0	113	0
Macoupin	2	0	0	0	0	1,261	0
Madison	23	14	0	1,124	0	51,415	31,362
Marion	61	36	0	2,377	0	133,958	80,054
Mason	1	0	0	0	0	1,404	0
Monroe	2	1	0	17	0	1,456	491
Montgomery	10	2	0	13	0	8,496	1,262
Moultrie	1	0	0	0	0	3,681	0
Perry	5	0	0	0	0	10,583	0
Pike	1	0	0	0	0	621	0
Putnam	1	0	0	0	0	2,000	0
Randolph	2	0	0	0	0	3,004	0
Richland	47	30	0	5,366	0	140,460	86,271
St. Clair	17	0	0	0	0	24,242	0
Saline	2	0	1	0	0.59	5,660	2,345
Sangamon	2	0	0	0	0	4,164	0
Shelby	12	2	0	17	0	26,362	3,911
Union	1	0	0	0	0	4,053	0
Wabash	194	144	0	12,164	0	425,978	295,680
Warren	1	0	0	0	0	810	0
Washington	24	10	0	198	0	35,785	12,907
Wayne	228	151	0	25,527	0	734,230	465,095
White	203	148	0	13,765	0	566,020	377,413
Will	1	0	0	0	0	900	0
Williamson	5	0	0	0	0	12,243	0
	1,791	1,065	9	130,851	26.12	4,611,695	2,766,912

[a] Includes old wells deepened.

One well was completed in the Ayers gas field, Bond County, during the year and it brought the number of producing wells in that field to 9. The field was discovered in 1922, covers 325 acres, and has produced a total of approximately

TABLE 6.—*Fields with Wells Producing from More than One Formation*

Field	County	Total Number of Combination Wells	Number of Wells and Producing Formations[a]
Iola	Clay	25	2CPBA, 1TA, 9CBA, 12BA, 1BPA
Sailor Springs Consolidated	Clay	1	1GC
Clay City Consolidated	Clay, Wayne	15	6RM, 1ARM, 1AM, 2CR, 1CB, 2AR, 2AL
Albion	Edwards	7	2BA, 1BM, 2BAM, 1WM, 1AL
Albion East	Edwards	1	1CAM
Mason South	Effingham	14	13BA, 1BR
Louden	Effingham, Fayette	211	111CP, 50CB, 19PB, 31CPB
Akin	Franklin	1	1AM
Benton North	Franklin	1	1PA
Inman East	Gallatin	13	1DCl, 1PWT, 1WTC, 2PaT, 2CW, 3ClT, 2TW, 1PaW
Inman West	Gallatin	6	1TCM, 5TC
Blairsville	Hamilton	2	1ALM, 1AM
Dale-Hoodville Consold	Hamilton	46	2AM, 1CM, 1LA, 1CB, 40BA, 1RM
Rural Hill	Hamilton	61	21AL, 19ALM, 8LM, 12AM, 1AR
King	Jefferson	6	3AL, 1 ALRM, 1ALM, 1LM
Markham City	Jefferson	1	1LM
Mt. Vernon	Jefferson	1	1LM
Patoka East	Marion	1	1BR
Salem	Marion	706	480BA, 222MS, 2BAM, 1AM, 1MD
Tonti	Marion	1	1BA
Dundas Consolidated	Richland, Jasper	5	1AM, 4RM
Friendsville	Wabash	2	1BiC, 1LM
Keensburg Consolidated	Wabash	15	1CBA, 1CA, 2BiC, 7BC, 2BA, 2AM
Maud	Wabash	1	1WM
Mt. Carmel	Wabash	26	2RM, 8BiC, 3BiCM, 9CM, 2CB, 1PeM, 1PeT
Irvington	Washington	1	1CB
Barnhill	Wayne	2	2RM
Barnhill East	Wayne	3	3LR
Boyleston Consolidated	Wayne	3	2LM, 1RM
Covington	Wayne	3	3LM
Johnsonville	Wayne	7	5AM, 2AL
Mt. Erie	Wayne	1	1RM
Sims	Wayne	18	1AL, 4LM, 1RM, 3LAM, 9AM
Sims North	Wayne	2	1RM, 1LM
Aden	Wayne, Hamilton	10	3AM, 1LRM, 5ALM, 1ALRM
Calvin North	White	1	1PePa
Centerville East	White	1	1LT
Iron	White	3	3TC
Maunie North	White	1	1BA
Maunie South	White	3	3TC
New Harmony Consold	White	181	5CP, 1TPB, 32PB, 1TB, 7CBM, 7WCBA, 3CBAM, 1TCM, 2WC, 31CB, 28CBA, 2WA, 3TCA, 3TA, 1TCB, 5AM, 15BA, 1 WB, 1TM, 1CM, 2WCBAM, 1WCB, 1CPM, 13CA, 2TC, 1CPB, 1BM, 1CPBAM, 1BiCA, 1PA, 1WM, 1WBM, 1RM, 1PeBA, IWCA, 2CPA
New Haven	White	4	2TC, 2CM
Phillipstown Consolidated	White	12	1CT, 2DC, 1PeClT, 1DClT, 5ClT, 1BM, 1BL
Stokes	White	6	1CA, 3CB, 2AT
Roland	White	31	2WP, 1WCP, 3BA, 1BAM, 1WCA, 3CB, 9WB, 9WA, 1CBA, 1CA
Mill Shoals	White, Hamilton	3	3AM
		1,465	

[a] Names of sands indicated as follows:

Pe, Pennsylvanian
Bi, Biehl
Pa, Palestine
D, Degonia
Cl, Clore
W, Waltersburg
T, Tar Springs
G, Glen Dean
H, Hardinsburg
C, Cypress
P, Paint Creek Stray
B, Bethel
A, Aux Vases
L, Levias
R, Rosiclare
M, McClosky
S, Salem
D, Devonian

235 million cubic feet of gas from the Bethel sandstone at a depth of about 950 feet.

NATURAL GASOLINE AND LIQUEFIED PETROLEUM GASES

Natural gasoline is produced in 34 plants in the old Southeastern field, the total capacity being approximately 8000 gal. daily. During 1943 these plants operated at only 75 per cent of capacity. In the fields discovered after Jan. 1, 1937, there are eight plants, including two in the Louden field, one in New Harmony Consolidated field, one in the Benton field, one in the Dale-Hoodville Consolidated field and three in Salem field. These eight plants have a total capacity of approximately 325,000 gal. daily. According to the U. S. Bureau of Mines,* 71,928,000 gal. of natural gasoline was produced in Illinois in 1943. The production of liquefied petroleum gas for 1943 amounted to 112,159,000 gal., according to the U. S. Bureau of Mines.

TABLE 7.—*Natural Gas Marketed in Illinois*

Field	County	Where Marketed	Amount Produced and Marketed, M Cu. Ft.
Russellville (gas)	Lawrence	Illinois, Indiana, Kentucky	1,236,000
Ayers (gas)	Bond	Greenville, Illinois	14,000
Salem......	Marion	Centralia, Salem, and Mt. Vernon, Illinois	650,000
Louden....	Fayette	Brownstown, St. Elmo, Vandalia, Illinois	510,000
			2,410,000

Natural gas accompanying oil production in the Louden field during 1943 is estimated at 7 billion cubic feet. The average daily production at the end of the year was approximately 15 million cubic feet. Approximately 13 million cubic feet of gas is processed daily by the Carter Oil Company's two repressuring plants and 5 million cubic feet of residue gas is injected into the producing sands. Residue gas from the two plants is furnished also to the G. H. and G. Pipe Line Co. for the towns of St. Elmo, Brownstown, and Vandalia, Ill., at the rate of 1.4 million cubic feet per day. The pipe-line company also receives 90,000 cu. ft. of gas daily from a well in the Louden field, which is producing from a basal Pennsylvanian sandstone.

The production of natural gas in the Salem field for 1943 is estimated at 20 billion cubic feet. At the end of the year the estimated daily production was 37 million cubic feet. Approximately 35 million cubic feet per day is processed by the three natural gasoline plants in the field. The Texas Company returns approximately 6 million cubic feet of residue gas daily to the producing sands in its repressuring operations in the Salem field. Residue gas from the Warren Petroleum Company's plant is supplied to the cities of Salem, Centralia, and Mt. Vernon, Ill. This consumption at the end of the year was approximately one million cubic feet per day.

The Dale-Hoodville Consolidated field, Hamilton County, produced an estimated 7 billion cubic feet of gas during 1943. Of this amount 6.2 billion cubic feet was processed at the Texas Company's Hoodville plant. Fifty-one million cubic feet of residue gas from this plant was returned to the field for injection. No residue gas is sold from this plant.

The Benton field, Franklin County, produced an estimated 3 billion cubic feet of gas during 1943 and 320 million cubic feet of gas from this field was processed at the Sunflower Petroleum Products Corporation plant. No residue gas is sold or returned to the Benton field for injection into the oil sand.

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* F. S. Lott, personal communication.

The New Harmony Consolidated field, White County, produced an estimated 8 billion cubic feet of gas during 1943. Of this, 4.9 billion cubic feet was processed at the Warren Petroleum Corporation's plant at Crossville, Ill., and 1.8 billion cubic feet of residue gas from this plant was returned to the leases for injection. No residue gas was sold.

The total gas production for 1943 for the fields discovered after Jan. 1, 1937, is estimated at 62,000 million cubic feet. A large part of this production is burned in flares.

SECONDARY RECOVERY

The starting of actual flooding operations by the Felmont Corporation on a part of the Patoka field in Marion County was the high light of secondary recovery in Illinois in 1943. The wide spacing of the wells and the indications of probable success for the method seem to open the way for wide application of water-flooding under Illinois conditions. Projects already begun before 1943—namely, the Forest Producing Corporation's operation on the Chrystler farm in the Siggins pool in Cumberland County and the Ohio Oil Company's operation in the Colmar-Plymouth pool in McDonough County—continued during 1943 with moderate success and considerable promise for the future. In the Clay City area the Pure Oil Co. produced commercially important quantities of oil by flooding the McClosky lime through three input wells.

Repressuring with gas continued in the three large areas in the Louden, Salem and New Harmony fields. The Ohio Oil Co. extended operations in Crawford County, so that 10 per cent of the drilled area is now under pressure. The results here have not been spectacular but have accounted for a considerable increase from the old wells. This increase, if it may be judged by results previously obtained in this territory, will be long lived.

Many other areas in the state are being favorably considered for extension of repressuring operations.

ACKNOWLEDGMENTS

The writers gratefully acknowledge the courtesy of the many companies and individuals who furnished data for this report. Mr. Frederick Squires, Mr. W. F. Meents, Mr. J. S. Yolton, Mr. R. F. Smith, and Mrs. Margaret Sands, all of the Survey staff, assisted in preparing the report.

Oil and Gas Activity in Indiana in 1943

By Ralph E. Esarey* and P. Hastings Keller†

Oil and gas activities in Indiana during 1943 continued to decline at about the same rate as in 1942. New development, production, and prospecting, all showed the results of Federal regulation, low price for crude oil and shortages of labor and materials. Several local stripper-well operations were shut down, but no large-scale abandonment has occurred as yet.

During the year, 277 holes were drilled for oil and/or gas, of which 99 were completed as oil wells, 19 as gas wells and 159 as dry holes. This record was a decline of 21 per cent over last year in the total number of completed tests, 20 per cent in the number of oil wells and 9.5 per cent in the number of gas wells. As in the previous year, most of the drilling (82 per cent) was in the southwestern part of the state, Gibson County ranking first, with 77 completions and 49 oil wells. Posey County was second, with 59 completions and 20 oil wells. The remaining 18 per cent of the drilling was in the old Trenton oil and gas area. The total footage drilled during the year was 482,799 ft., a decline of 18 per cent from the previous year. Of this, 146,559 ft. was wildcat footage.

The total initial production of the oil wells completed was 6362 bbl. and of the gas wells was 2,562,000 cu. feet.

Three tests in the old Trenton area were drilled into the Cambrian and reported nothing more than tar residue. A Devonian test was to be made in the Griffin field in the Wabash River but owing to the delay caused by Federal restrictions this test did not get started in 1943. It is expected to spud in March 1944.

The new discoveries in 1943 were virtually all in the southwestern part of the state, and all, so far, one-well pools, except the North Owensville pool, in Gibson County. The latter was brought in during the month of February and by the end of the year nine wells were producing in the pool, with a reported initial yield of 1260 bbl. per day. By the end of the year it had a daily average production of 401 bbl. and an accumulated production of 39,129 bbl. The average gravity of the oil is reported to be 35.6.

On the Ohio-Indiana state line, early in 1943, a new pool was opened up in the old Trenton area. The discovery well was on the Ohio side of the line. An offset well was completed on the Indiana side, with an initial yield of 64 bbl., and settled down to 5 bbl. per day. This well produced 1154 bbl. up to Dec. 31, 1943. There was no further development here, because of the Federal Conservation Order M-68, restricting drilling to one well on 40 acres. The development pattern usually followed in this area is one well to 5 acres.

The E. Rogers field was extended by one pool (Table 4).

Most of the development in the oil-field pools during the year took place in the Kirksville pool, in Gibson County, and the Caborn pool, in Posey County.

The crude-oil production in 1943 was approximately 5,273,000 bbl., a decline of 29 per cent from the previous year. The Griffin field, of Gibson and Posey Counties,

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TABLE 1.—*Oil and Gas Production in Indiana*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
1	Cannelburg, *Daviess*	1925	690	120,700	0		*x*	0	80	1	0
2	Glendale-Hudsonville, *Daviess*	1929	1,200	0	0		*x*	*x*	66	0	6
3	North Glendale, *Daviess*	1941	180	0	0		*x*	*x*	10	2	3
4	Veale, *Daviess*	1926	420	*x*	*x*		0	0	81	0	0
5	Greensburg, *Decatur*	1893	37,010	0	0		4,739.7	228.9	401	2	0
6	Columbia, *Gibson*	1941	90	4,587	502		0	0	5	0	0
7	Fleenor, *Gibson*[1]	1940	20	4,500	0		0	0	1	0	0
8	Francisco, *Gibson*	1929	730	200,434	11,234		1,282.7	*x*	46	0	8
9	Hazelton, *Gibson*	1941	1,160	331,485	144,885		*x*	*x*	27	8	0
10	Johnson, *Gibson*	1941	20	6,676	1,976		0	0	2	0	1
11	Kirksville, *Gibson*	1941	420	115,657	74,457		*x*	*x*	29	14	4
12	Mt. Carmel, *Gibson*[2]	1941	30	10,818	5,518		0	0	3	3	0
13	North Owensville, *Gibson*	1943	150	39,129	39,129		0	0	10	10	0
14	Owensville, *Gibson*	1940	20	4,900	0		0	0	1	0	1
15	Patoka, *Gibson*	1941	40	4,900	0		0	0	2	0	2
16	Somerville, *Gibson*	1942	40	5,636	3,436		0	0	4	2	0
17	West Princeton, *Gibson*	1903	1,870	*x*	*x*		*x*	0	151	0	*x*
18	Griffin, *Gibson, Posey*	1938	4,070	15,422,690	2,393,390		0	0	430	10	10
19	Mumford Hill, *Gibson, Posey*	1939	350	*x*	*x*		0	0	13	1	0
20	Loconia, *Harrison*	1910	6,605	0	0		*x*	*x*	130	1	0
21	Trenton, *Jay* and many counties[5]	1886	778,080	*x*	*x*		*x*	*x*	26,624	22	2
22	Monroe City, *Knox*	1922	400	*x*	*x*		0	0	15	0	0
23	Mt. Carmel, *Knox*[2]		50		*x*		*x*	0	0	2	0
24	Oaktown	1930	1,080	*x*	*x*		2,004,431	42,511	82	0	0
25	St. Francisville, *Knox*[2]	1942	40	12,408	8,472		0	0	3	0	0
26	St. Thomas, *Knox*	1940	80	72,052	6,952		0	0	6	0	0
27	Loogootee, *Martin, Daviess*	1900	2,200	*x*	*x*		*x*	*x*	58	0	0
28	Unionville, *Monroe*	1929	1,400	0	0		*x*	*x*	18	0	0
29	Bristow, *Perry*	1929	270	*x*	*x*		0	0	45	0	0
30	Troy-Tell City, *Perry, Spencer*	1928	940	*x*	*x*		*x*	*x*	83	0	0
31	Alford, *Pike*[4]	1919	1,090	*x*	*x*		*x*	*x*	97	0	5
32	Iva, *Pike*	1935	160	0	0		*x*	*x*	5	0	0
33	Spurgeon, *Pike*	1941	20	26,020	10,820		0	0	2	0	0
34	Oakland City, *Pike, Gibson*	1907	3,110	*x*	*x*		*x*	0	62	0	1
35	Oatsville-Wheeling, *Pike, Gibson*	1919	1,950	*x*	*x*		0	0	259	3	0
36	Tri County, *Pike, Gibson*	1925	370	*x*	*x*		*x*	0	74	0	0
37	Union-Bowman, *Pike, Gibson*	1916	5,180	*x*	*x*		*x*	*x*	408	5	7

[b] Footnotes to column heads and explanation of symbols are given on page 270.
[1] Abandoned. [2] Extension from Illinois. [4] Includes Rush gas field.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil		Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift														
1	0	27	0	*x*	*x*		*x*	*x*	Chester, MisU	S	P	630	10	A	Chester	895
2	0	0	15	275	*x*		*x*	*x*	Barker, MisU	S	P	650	10	T	St. Louis	1,575
3	0	0	6	124.4	*x*		*x*	*x*	Cypress, MisU	S	P	678	*x*	D	MisL	851
4	0	31	0	*x*	*x*		*x*	*x*	McClosky, MisL	Ls	P	1,161	10	A	Devonian	2,618
5	0	0	164	275	*x*		*x*	*x*	Trenton, Ord	Ls	P	886	10	A	Pre-Cambrian	3,055
6	0	4	0	*x*	*x*		36	*x*	Cypress, MisU	S	P	1,190	6	D	MisU	1,536
7	0	0	0	*x*			*x*	*x*	McClosky, MisL	Ls	P	2,673	8	D	MisL	2,714
8	0	8	1	690	*x*		33	*x*	Brown, MisU McClosky, MisL	S Ls	P P	1,340 1,600	 25	A	Ordovician	4,006
9	0	27	0	*x*			39.5 *x*	*x* *x*	McClosky, MisL Salem, MisL Osage, MisL	Ls Ls Ls	P P P	1,735 2,035 2,402	5 5 10	A	Silurian	3,150
10	0	1	0	*x*	*x*		32	*x*	Pennsylvanian, Pen	S	P	1,095	6	D	MisL	2,802
11	0	23	2	*x*	*x*		38	*x*	Hardinsburg, MisU McClosky, MisL	S Ls	P P	1,333 1,787	22 5	A	MisL	1,956
12	0	3	0	*x*	*x*		38	*x*	Cypress, MisU	S	P	1,976	12	19	MisL	2,355
13	0	10	0	*x*	*x*		35.6	*x*	Cypress, MisU Bethel, MisU McClosky, MisL	S S Ls	P P P	1,575 2,129 2,440	12 3 8	*x*	MisL	2,494
14	0	0	0	*x*	*x*		39.5	*x*	St. Louis, MisL	Ls	P	2,690	7	D	MisL	2,703
15	0	0	0	*x*	*x*		40.5	*x*	McClosky, MisL	Ls	P	2,250	*x*	D	Ste. Genevieve	2,300
16	0	4	0	*x*	*x*		*x*	*x*	Tar Springs, MisU	S	P	1,117	20	D	MisU	2,266
17	0	7?	0	*x*	*x*		*x*	*x*	West Princeton, PenL		P	890	*x*	A	St. Louis	3,905
18	0	418	0	*x*	*x*		38	*x*	Pennsylvania, Pen Waltersburg, MisU Tar Springs, MisU Cypress, MisU Aux Vases, MisU McClosky, MisU	S S S S S Ls	P P P P P P	1,250 2,050 2,125 2,500 2,750 2,850	15 20 25 20 8	A	Osage	3,526
19	0	10	0	*x*	*x*		*x*	*x*	Cypress, MisU McClosky, MisL	S Ls	P P	2,458 2,917	17 20	D	MisL	3,047
20	0	0	33	175	*x*		*x*	*x*	New Albany, Dev	Sh	Fis	690	20	M	Trenton	1,770
21	0	200	51	325	*x*		36	*x*	Trenton, Ord	L, D	P, Fis	900	10	A	Pre-Cambrian	3,996
22	0	7	0	*x*	*x*		*x*	*x*	Mansfield, Pen Cypress, MisU Mooretown, MisU Paoli, MisU	S S S Ls	P P P P	880 1,235 1,465 1,520	10 15 10 *x*	M	Salem	1,935
23	0	2	0	*x*	*x*		*x*	*x*	Cypress, MisU McClosky, MisL	S Ls	P P	1,981 2,292	11 3	*x*	Ste. Genevieve	2,339
24	0	5	26	281	*x*		35	*x*	Staunton, PenL	S		580 790	15	ML	Ste. Genevieve	1,592
25	0	3	0	*x*	*x*		39.5	*x*	Bethel, MisL	S	P	1,737	13	A	MisL	1,936
26	0	6	0	*x*	*x*		*x*	*x*	McClosky, MisL	Ls	P	1,871	8	O	Ste. Genevieve	2,050
27	0	14?	0	*x*	*x*		*x*	*x*	Mooretown, MisU	S	P	532	10	A	Trenton	3,025
28	0	0	13	250	*x*		*x*	*x*	Coniferous, DevM	Ls	P	800	40	AF	Trenton	2,102
29	0	4	0	*x*	*x*		33	*x*	Tar Springs, MisU Cypress, MisU Elwren, MisU	S S S	P P P	280 465 503	7 10 9	ML	Ste. Genevieve	710
30	0	27	2	*x*	*x*		34	*x*	Sample, MisU Cypress, MisU Mooretown, MisU	S S S	P P P	468, 714 747 805	*x* *x* *x*	NMF	MisL	1,708
31	0	7	20	*x*	*x*		38	*x*	Oakland City, MisU Brown Sands, MisU	S S	P P	630, 1,080 1,130	10 10	A	St. Louis	1,413
32	0	0	5	*x*	*x*		*x*	*x*	Hardinsburg, MisU	S	P	750	8	D	MisL	1,174
33	0	2	0	*x*	*x*		34.5	*x*	Cypress, MisU	S	P	1,143	8	D	MisU	1,151
34	0	34	0	*x*	*x*		28	*x*	Oakland City, MisU Brown, MisU	S S	P P	1,085 1,107	10 10	A	Paoli	1,444
35	0	189	0	*x*	*x*		32	*x*	Sample, MisU Cypress, MisU Mooretown, MisU Paoli, MisU	S S S S	P P P P	1,250 1,270 1,340 1,725	*x* *x* *x* *x*	A	Harodsburg	2,050
36	0	13	0	*x*	*x*		34	*x*	Brazil, PenL Oakland City, MisU	S S	P P	315 1,317	10 10	A	Ste. Genevieve	1,998
37	0	273	0	*x*	*x*		35	*x*	Hardinsburg, MisU Cypress(?), MisU Mooretown, MisU Paoli, MisU McClosky, MisL	S S S Ls Ls	P P P P P	1,290 945 1,233 1,233 1,778	10 5 7	A	Salem	2,205

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
38	Bufkin, *Posey*	1940	150	129,147	31,747		0	0	10	0	0
39	Caborn, *Posey*	1940	730	570,790	219,490		*x*	*x*	41	*x*	1
40	Caborn, West, *Posey*	1941	80	34,137	11,037		0	0	7	0	0
41	College, *Posey*	1940	100	92,846	17,646		0	0	7	1	0
42	Grafton, *Posey*[1]	1942	20	692	0		0	0	1	0	0
43	Half Moon, *Posey*	1942	20	6,499	2,599		0	0	1	0	0
44	Hovey Lake, *Posey*	1942	20	3,789	2,789		0	0	1	0	0
45	Inman, East, *Posey*	1943	10	2,246	2,246		0		1	1	0
46	Lamott, *Posey*	1941	40	35,796	13,296		0	0	4	0	0
47	Mt. Vernon, *Posey*	1941	310	1,212,257	483,057		0	0	23	1	3
48	New Harmony, *Posey*	1939	430	2,204,297	528,397		0	0	30	4	0
49	New Haven, *Posey*[2]	1942	20	14,359	7,459		0	0	1	0	0
50	Point, *Posey*	1942	20	27,200	6,900		0	0	1	0	0
51	Prairie, *Posey*	1942	20	9,933	2,583		0	0	1	0	0
52	Rapture, *Posey*[1]	1941	20	595	0		0	0	1	0	0
53	Ridge, *Posey*	1942	20	2,559	1,559		0	0	1	0	0
54	Rogers, *Posey*	1943	20	10,328	10,328		0	0	2	2	0
55	St. Wendells, *Posey*	1934	240	*x*	*x*		0	0	28	0	0
56	Stooker, *Posey*	1942	40	25,304	9,804		0	0	2	0	0
57	Upton	1943	10	606	606		0	0	1	1	0
58	Welborn, *Posey*	1941	20	13,598	4,098		0	0	1	0	0
59	Heusler, *Posey, Vanderburgh*	1938	*x*	1,153,746	273,046		0	0	51	0	0
60	Enterprise, *Spencer*	1939	170	*x*	*x*		0	0	11	5	0
61	Eureka, *Spencer*	1942	10	*x*	*x*		0	0	1	0	0
62	Grandview, *Spencer*		*x*	*x*	*x*		0	0	7	1	0
63	Hatfield, *Spencer*	1941	130	*x*	*x*		0	0	14	0	2
64	Rock Hill, *Spencer*	1929	310	*x*	*x*		0	0	24	0	0
65	Rockport, *Spencer*	1939	*x*	*x*	*x*		*x*	*x*	66	2	1
66	Richland, *Spencer*	1943	40	*x*	*x*		0	0	1	1	0
67	Gentryville, *Spencer, Warrick*		260	*x*	*x*		0	0	13	0	3
68	Dodds Bridge, *Sullivan*	*x*	400	*x* 174,245	*x* 96,545		0 0	0 0	101 6	0 0	0 0
69	Marts, *Sullivan*	1932	200	0	0		*x*	*x*	16	0	0
70	Shelburn-Sullivan, *Sullivan*[6]	1911	5,780	*x*	*x*		*x*	*x*	1,000	0	3
71	Vanderburgh, *Vanderburgh*	1931	600	*x*	*x*		0	0	95	0	0
72	Vaughn, *Vanderburgh*[1]	1941	120	1,214	0		0	0	1	0	0
73	Vienna, *Vanderburgh*[4]	1933	*x*	*x*	*x*		0	0	103	1	0
74	Vernon Heights, *Vanderburgh*	1941	190	*x*	*x*		0	0	16	7	1
75	Prairie Creek, *Vigo*	1937	460	692,994	93,894		0	0	24	0	1
76	Riley, *Vigo*	1906	310	*x*	*x*		0	0	33	0	0
77	Siosi, *Vigo, Sullivan*	1926	880	3,231,401	111,401		0	0	86	0	2
78	Millersburg, *Warrick*[1]	1941	20	*x*	*x*		0	0	1	0	1

[6] Formerly called Shelburn-Graysville.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
38	0	10	0	x	x		32-34	x	Pennsylvanian, Pen Cypress, MisU	S S	P P	634 1,130 2,382	x 23 18	A	St. Louis	2,863
39	0	40	x	x	x		27-34	x	Pennsylvanian, Pen Waltersburg, MisU Tar Springs, MisU Cypress, MisU	S S S S	P P P P	362 1,095 1,880 1,990 2,367	9 12 x 10	A	Salem	2,740
40	0	5	0	x	x		34	x	Cypress, MisU	S	P	2,497	6	A	MisL	2,670
41	0	5	0	x	x		38.5	x	Aux Vases, MisU McClosky, MisL	S Ls	P P	2,505 2,618	10 4	D	St. Louis	2,729
42	0	0	0	x	x		36	x	Tar Springs, MisU	S	P	2,139	7	D	MisL	3,010
43	0	1	.0	x	x		x	x	Aux Vases, MisU	S	P	2,609	11	D	MisL	2,653
44	0	1	0	x	x		x	x	Pennsylvanian, Pen	S	P	1,095	10	D	Pen	1,135
45	0	1	0	x	x		x	x	Tar Springs, MisU	S	P	2,039	10	x	McClosky	2,809
46	0	4	0	x	x		35.5	x	Tar Springs, MisU	S	P	1,945	6	D	Ste. Genevieve	2,812
47	0	20	0	x	x		35.5	x	Waltersburg, MisU Cypress, MisU	S S	P P	2,000 2,425	18 23	A	St. Louis	3,000
48	0	30	0	x	x		36.5	x	Waltersburg, MisU Tar Springs, MisU Cypress, MisU McClosky, MisL	S S S Ls	P P P P	2,172 2,295 2,610 2,968	35 10 11 4	A	St. Louis	3,028
49	0	1	0	x	x		x	x	Cypress, MisU	S	P	2,457	7	A	MisL	2,925
50	0	1	0	x	x		39	x	McClosky, MisL	Ls	P	2,760	4	D	MisL	2,908
51	0	1	0	x	x		x	x	McClosky, MisL	Ls	P	2,839	12	D	MisL	2,968
52	0	0	0	x	x		39	x	McClosky, MisL	Ls	P	2,972	6	D	MisL	3,109
53	0	1	0	x	x		x	x	McClosky, MisL	Ls	P	2,737	5	D	MisL	2,742
54	0	2	0	x	x		36	x	Clore, MisU Waltersburg, MisU	S S	P P	1,887 2,195	3 10	x	MisU	2,963
55	0	26	0	x	x		x	x	Mansfield, PenL	S	P	1,007	30	ML	Chester	1,920
56	0	2	0	x	x		38.5	x	McClosky, MisL	Ls	P	2,612	7	D	MisL	2,621
57	0	1	0	x	x		x	x	Tar Springs, MisU	S	P	2,143	7	x	MisU	2,150
58	0	1	0	x	x		36	x	Cypress, MisU	S	P	2,476	30	D	Ste. Genevieve	2,817
59	0	43?	0	x	x		27-35	x	Waltersburg, MisU Tar Springs, MisU	S S	P P	1,750 1,855	25 25	AF	Ste. Genevieve	2,643
60	0	11	0	x	x		32-36	x	Palestine, MisU Cypress, MisU McClosky, MisL	S S Ls	P P P	915 1,404 1,571	10 8 8	x D	Mis L	1,745
61	0	1	0	x	x		38	x	McClosky, MisL	Ls	P	1,652	2	D	MisL	1,674
62	0	6	0	x	x		x	x	Aux Vases, MisU	S	P	982	10	x	MisU	1,077
63	0	12	0	x	x		34	x	Waltersburg, MisU	S	P	1,029	15	A	St. Louis	1,783
64	0	21	0	x	x		34	x	Sample, MisU	S	P	1,310	10	MC	Ste. Genevieve	1,500
65	0	16	38	x	x		33.5	x	Pennsylvanian, PenL Palestine, MisU	S S	P P	885 950	10 10	A	St. Louis	1,707
66	0	1	0	x	x		x	x	McClosky, MisL	Ls	P	1,540	10	x	MisL	1,548
67	0	0	0	x	x		x	x	Tar Springs, MisU	S	P	725 634	33	D	MisL	1,241
68	0	x	0	x	x		x	x	Pennsylvanian, PenL	S	P	700	x	A	Devonian	2,386
	0	6	0	x	x		46	x	Devonian, Dev	Ls	P	2,337	13	A		
69	0	0	9	x	x		x	x	Pennsylvanian, Pen	S	P	313 298	9	D	Pennsylvanian	628
70	0	273?	18?	110	x		35	x	Pennsylvanian, Pen Harrodsburg, MisL	S Ls	P P	560 640 730 800 1,400	x x	AN	Silurian	2,875
71	0	53	0	x	x		30.5	x	Silurian, Sil Mansfield, PenL	Ls S	P P	2,270 899	x x	ML	Ste. Genevieve	2,435
72	0	0	0	x	x		34	x	Waltersburg, MisU (below)	S	P	1,647	8	D	MisL	2,562
73	0	34	1	x	x		29	x	Providence, Pen	S	P	468	16	x		
									Mansfield, PenL	S	P	1,007	30	NL	Chester	1,920
74	0	15	0	x	x		x	x	Waltersburg, MisU McClosky, MisL	S Ls	P P	1,770 2,502	16 15	A	MisL	2,653
75	0	14	0	x	x		37	x	Niagaran, Dev-Sil	Ls	P	2,074	x	O	Silurian	2,232
76	0	1	0	x	x		50	x	Niagaran, Dev	Ls	P	4,605	x	A	Niagaran	1,802
77	0	42	0	x	x		39	x	Niagaran, Dev-Sil	Ls	P	2,100	x	D	Trenton	3,554
78	0	0	0	x	x		x	x	McClosky, MisL	Ls	P	1,887	3	D	MisL	1,956

TABLE 2.—*Summary of Drilling Operations in Indiana*

Important Wildcats Drilled in 1943

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks*
		Sec.	Tp.	Rge.					Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Adams	35	25N	13 E	2,500±	Sil	Cambrian	R. O. McKee						T. A.
2	Bartholomew	25	8N	4 E	1,168	Dev	(Trenton) Ord	James C. Hamilton						D. and A.
3	Clay	27	9N	6 W	1,724	Pen	Devonian	H. C. Detrick						D. and A.
4	Dearborn	15	6N	1 W	864	Ord (Cincin.)	Ord (St. P.)	Central U.S. Oil & Gas Co.						T. A.
5	Delaware	13	20N	11 W	1,760	Sil	Ord (St. P.)	W. E. Weidler						T. A.
6	Fountain	2	18N	8 W	1,700	Pen	Ord (Trenton)	Fountain Oil Co.						T. A.
7	Gibson	25	2 S	12 W	2,454	Pen	Mis (St. G.)	Superior Oil Co.	187		2½″ tubing			
8	Gibson	7	2 S	11 W	2,373	Pen	Mis (St. G.)	Superior Oil Co.						D. and A.
9	Gibson	31	3 S	10 W	2,283	Pen	Mis (St. G.)	Phillips Pet. Co.						D. and A.
10	Gibson	19	3 S	11 W	2,669	Pen	Mis (St. L.)	Kingwood Oil Co.						D. and A.
11	Gibson	36	3 S	11 W	2,341	Pen	Mis (St. L.)	Phillips Petr. Co.						D. and A.
12	Gibson	11	3 S	12 W	2,624	Pen	Mis (Ste. G.)	W. H. Bears						D. and A.
13	Gibson	30	3 S	12 W	2,790	Pen	Mis (Ste. G.)	Superior Oil Co.						D. and A.
14	Harrison	36	3 S	3 E	826	Mis (Chester)	Devonian	Harrison Dev. Co.						D. and A.
15	Harrison	5	8 S	4 E	828	Mis (Chester)	Devonian	Harrison Dev. Co.		50,000		80		
16	Jay	5	22N	15 E	1,567	Sil	Ord (St. Peter)	Muehlhausen & Smith		100,000				
17	Jennings	23	5N	7 E	1,336	Dev	Ord (Trenton)	Comiskey Oil Associates						D. and A.
18	Jennings	12	7 N	7 E	1,200	Dev	Ord (Trenton)	Ohio Valley Oil & Gas Co.						D. and A.
19	Jennings	30	7 N	8 E	1,537	Dev	Ord (St. P.)	Ohio Valley Oil & Gas Co.						D. and A.
20	Knox	5	5N	7 W	2,400	Pen	Devonian	Sun Oil Co.						D. and A.
21	Knox	8	5N	7 W	2,352	Pen	Devonian	Sun Oil Co.						D. and A.
22	Lake	5	22N	9 W	2,438	Sil	Cambrian	The Peter Fox Sons Co.						D. and A.
23	Lake	30	32N	9 W	1,315	Sil	Ord (St. P.)	Walter Elliott Tr.						D. and A.
24	La Porte	5	36N	2 W	1,565	Mis	Ord (Trenton)	Shell Oil Co.						D. and A.
25	La Porte	7	37N	2 W	1,528	Dev	Trenton (Ord)	Lyman, Steffy & Rhodes						D. and A.
26	Porter	3	36N	5 W	1,125	Dev	Trenton (Ord)	Tri States Synd.						D. and A.
27	Posey	24	8 S	14 W	2,703	Pen	Mis (St. Louis)	Sinclair, Wyoming Oil Co.						D. and A.
28	Posey	26	8 S	14 W	2,873	Pen	Mis (St. Louis)	Sinclair, Wyoming Oil Co.						D. and A.
29	Posey	35	5 S	13 W	2,967	Pen	Mis (St. Louis)	Rossi & Kiltz						D. and A.
30	Posey	4	6 S	14 W	3,115	Pen	Mis (Ste. Gen.)	Bur-Kan Pet. Co.						D. and A.
31	Posey	29	4 S	13 W	2,963	Pen	Mis (Ste. Gen.)	Superior Oil Co.	32 oil 133 W		pump		2½″	
32	Posey	32	6 S	14 W	2,150	Pen	Mis (Chester)	Bennett Bros. Dlg. Co.	115 oil 20 W		pump		2½″	
33	Posey	29	7 S	12 W	2,807	Pen	Mis (Ste. Gen.)	The Carter Oil Co.						D. and A.
34	Posey	6	7 S	14 W	3,009	Pen	Mis (Ste. Gen.)	Cherry & Kidd						D. and A.
35	Posey	14	7 S	14 W	2,901	Pen	Mis (St. Louis)	Carter Oil Co.						D. and A.
36	Posey	34	7 S	14 W	2,806	Pen	Mis (Ste. Gen.)	Carter Oil Co.						D. and A.
37	Posey	25	7 S	15 W	2,700	Pen	Mis ?	Baldwin et al						D. and A.

* T. A., temporarily abandoned; D. and A., dry and abandoned.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1943

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Sec.	Tp.	Rge.					Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
38	Posey	19	8 S	13 W	2,650	Pen	Mis (Ste. Gen.)	A. J. Hammer						D. and A.
39	Scott	35	4N	7 E	1,552	Dev	Ord (St. Peter)	E. T. Hart						D. and A
40	Spencer	34	6 S	5 W	1,098	Pen	Mis (Ste. Gen.)	O. D. Vickers						D. and A.
41	Spencer	11	7 S	7 W	1,548	Pen	Mis (Ste. Gen.)	L. L. Benoist	4 bbls. oil		pump			
42	Sullivan	15	9N	9 W	2,407	Pen	Sil	The Ohio Oil Co.						D. and A.
43	Sullivan	22	9N	9 W	1,121	Pen	Mis (Ste. Gen.)	The Ohio Oil Co.						D. and A.
44	Tippecanoe	22	24N	3 W	1,040	Dev	Ord (Trenton)	Milo Ritchie						D. and A.
45	Vanderburgh	2	5 S	11 W	2,566	Pen	Mis (St. Louis)	Cherry & Kidd						D. and A.
46	Vanderburgh	11	7 S	10 W	2,380	Pen	Mis (St. Louis)	O'Neal & Lacy						D. and A.
47	Vanderburgh	3	7 S	11 W	2,500	Pen	Mis	Roy Lee Tr.						D. and A.
48	Vanderburgh	18	7 S	11 W	2,592	Pen	Mis (Ste. Gen.)	Clark Nye						D. and A.
49	Vanderburgh	22	7 S	11 W	2,566	Pen	Mis (Ste. Gen.)	Geo. E. Nelson et al.						D. and A.
50	Warrick	36	4 S	7 W	1,520	Pen (Alleg.)	Mis (Ste. Gen.)	White Eagle Oil Co.						D. and A.
51	Warrick	3	4 S	6 W	1,261	Pen	Mis (Ste. Gen.)	Mo Bu Stro Oil Co.						D. and A.
52	Warrick	11	4 S	8 W	2,500	Pen	Mis (Osage)	W. P. Dearing						D. and A.
53	Warrick	20	6 S	8 W	2,027	Pen	Mis (Ste. Gen.)	Ohio Oil Co.						D. and A.
54	Warrick	36	6 S	9 W	2,140	Pen	Mis (Ste. Gen.)	Waller Chenault et al.						D. and A.
55	Wayne	22	13N	1 W	3,330	Sil	Cambrian	Wayne County Producers						D. and A.
56	Wayne	34	13N	1 W	1,277	Sil	Ord (Trent.)	Wayne County Producers						D. and A.
57	White	35	28N	4 W	928	Dev	Ord (Trent.)	C. L. Maguire						D. and A.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1943	57	17
Number of oil wells completed during 1943	197	5
Number of gas wells completed during 1943	19	0
Number of dry holes completed during 1943	84	75

TABLE 3.—*Completions by Counties in Indiana in 1943*

County	Completions	Producers		Total Initial Production of		Footage Drilled
		Oil	Gas	Oil, Bbl.	Gas, Cu. Ft.	
Adams	1	0	0	0	0	2,399
Bartholomew	1	0	0	0	0	1,168
Blackford	1	0	0	0	0	957
Clay	1	0	0	0	0	1,724
Daviess	14	1	3	4	1,472,000	11,371
Dearborn	2	0	0	0	0	1,300
Decatur	3	0	3	0	450,000	2,693
Delaware	2	0	0	5	0	3,052
DuBois	2	0	0	0	0	2,002
Fountain	1	0	0	0	0	1,583
Gibson	77	49	0	3,902	0	170,193
Harrison	3	0	1	0	50,000	2,594
Henry	3	0	3	0	75,000	2,750
Jasper	1	0	0	0	0	148
Jay	12	7	2	93	125,000	13,898
Jennings	3	0	0	0	0	4,073
Knox	10	4	0	119	0	19,965
Lake	3	0	0	0	0	4,153
La Porte	2	0	0	0	0	3,093
Madison	1	0	0	0	0	1,030
Marion	1	0	1	0	100,000	870
Marshall	1	0	0	0	0	285
Newton	1	0	0	0	0	875
Perry	1	0	0	0	0	380
Pike	8	0	0	0	0	9,207
Porter	1	0	0	0	0	1,125
Posey	59	20	1	1,440	25,000	142,126
Randolph	5	1	1	60	25,000	5,680
Rush	2	0	2	0	115,000	7,771
Scott	1	0	0	0	0	1,552
Spencer	25	10	1	374	100,000	26,435
Sullivan	2	0	0	0	0	3,528
Tippecanoe	1	0	0	0	0	1,040
Vanderburgh	17	7	1	370	25,000	32,246
Warrick	6	0	0	0	0	10,635
Wayne	2	0	0	0	0	4,607
White	1	0	0	0	0	928
	277	99	19	6,362	2,562,000	482,799

which produced approximately 2,395,000 bbl. of oil, accounted for nearly half of the total production of the state.

The price of crude oil was $1.22 a barrel for the old fields and $1.37 for the new fields in southwestern Indiana. In the old Trenton field in northeastern Indiana, the producers received $1.60 a barrel for the crude, which was used as fuel oil.

Figures on the total production of natural gas in 1943 received to date are not complete, but the yield from the three largest gas fields in the state are as follows: Rockport gas field, in Spencer County, which is the largest in total yield, was 500,151,000 cu. ft.; Greensburg field, in Decatur County, second largest, was 228,894,100 cu. ft., and Unionville field, in Monroe County, third largest, was 168,710,000 cu. ft. The total yield of these three fields show a decline of 15 per cent over their 1942 yield.

Warren Petroleum Corporation, operating in the Griffin field, processed a total of 1,700,923 M cu. ft. of casinghead gas.

TABLE 4.—*New Pools Discovered and Extensions to Fields in Indiana in 1943*

Field	County	Company and Farm	Location	Total Depth, Ft.	Producing Formation	Depth to Top, Ft.	Initial Production, Bbl.	Date of Completion	Number of Wells in Pool 12 31 43
N. Owensville......	Gibson	Superior Oil Company, No. 1, S. B. Thompson	SE NW 25-2S-12W	2,454	McClosky	2,411–2,417	187	2-23-43	9
Rogers............	Posey	Superior Oil Company No. 1, J. W. Carr et al.	NE SW 29-4S-13W	2,963 Plugged back to 1,948	Clore sand	1,885–1,890	32 oil, 133 water	1- 6-43	1
Upton............	Posey	Bennett Bros. Drill Co., No. 1, John W. Spencer	SE SW 32-6S-14W	2,150	Tar Springs	2,143–2,150	115 oil, 20 water	12-22-43	1
Wildcat...........	Spencer	Wm. B. Bateman, Trustee, No. 1, John Ernst	NW SW 8-6S-4W	802	Jackson	798– 802	10	11-10-43	1
Wildcat...........	Spencer	L. L. Benoist, No. 1 Clyde A. & Flora Richards	NE SE 11-7S-7W	1,548	McClosky	1,541–1,545	4	12- 8-43	1
EXTENSIONS TO FIELDS									
E. Rogers.........	Posey	E. E. Beatty, No. 1 F. L. Bailey	SW SE 28-4S-13W	2,215	Walt. sand	2,195–2,205	150 nat.	9-15-43	1

Oil and Gas Fields of Kansas during 1943

By W. A. Ver Wiebe*

Spurred on by the very high demands for new crude supplies resulting from World War II, the oil men of Kansas strained every effort in 1943 to find as many new pools as possible. In all, 1761 test wells were drilled, of which 895 were successful in finding new oil supplies and 32 in finding new gas supplies. The total number of wildcat wells drilled in Kansas was 577, including the so-called "extension wildcats," which are located less than 2 miles from production.

As a result of the very determined effort to find new oil reserves, 49 of the wildcat test wells found new oil pools in western Kansas and 7 found new oil pools in eastern Kansas. There were 289 rank wildcat tests, and among these 28 were successful ventures. They are responsible for 26 of the new oil pools recorded for the year and 2 of the new gas pools recorded. The ratio of dry holes to producing wells among such rank wildcats is thus approximately 10 to 1 (289 dry and 28 good). This compares with a ratio of 11:1 in 1942 and 6:1 in 1941; the same in 1940 and 5:1 in 1939.

With nearly all wells flowing to their maximum economic capacity, the total production for Kansas during 1943 reached a new high; that is, 107,700,000 bbl., compared with 97,000,000 during the previous year. Similarly, the amount of gas sold during 1943 made a new high point on the production curve. The total amount was 122 billion cubic feet, compared with about 98½ billion cubic feet for the year previous. As usual, the large Hugoton field of southwestern Kansas accounted for approximately half of the total gas production.

Highlights of the Year

Despite the fact that 56 new pools were found in Kansas during 1943, it must be admitted that the future reserves of the state have not been increased greatly. Most of the new pools seem to be of minor value, although it is admittedly impossible to gauge the future production of any pool in Kansas with any exactitude. Judging by the later performance of some of the pools found in 1942 and in 1941, less than five of the new pools are likely to make any great contribution to the state's future oil reserves. Taking up the counties of Kansas in alphabetical order, the following statements summarize the highlights of the year.

In Graham County, the Morel pool was extended to the southeast and this pool now promises to become one of the important pools of western Kansas. Several of the older wells have already contributed more than 100,000 bbl. of oil, and such a figure is considered very satisfactory in Kansas.

In McPherson County, important new reserves were found by persistent drilling in township 17 S., R. 1. W., the most northeastern township of the county. Many new wells in older pools and discovery wells in new pools make this region look promising. The Lindsborg pool, which had a sensational revival during 1942, was also extended in a number of directions and has now become a rather large producing area with a fairly high future potential capacity.

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TABLE I.—*Oil and Gas Pools Discovered in* 1943

	County, Field and Location	Operator and Fee	Geologic Formation	Depth, Ft.	Month	Initial Production
						BARRELS
	Barber County					
1	Skinner, 29-31-14W	Deep Rock No. 1 "B" Skinner	Viola	4,626-4,640	Dec.	200
2	Turkey Creek, 20-30-15W	Aladdin No. 1 Nat. Gypsum	Sand	4,430-4,456	Apr.	60
	Barton County					
3	Ainsworth SE., 11-17-13W	Blck. Marshall No. 1 Hitchman	Arbuckle	3,358-3,366	Dec.	100
4	Ames, 22-18-11W	Jonas No. 1 Ames	Lans. K. C.	3,042-3,048	July	290
5	Bahr, 26-18-15W	Clum No. 1 Bahr	Reagan	3,495-3,506	Aug.	140
6	Barrett, 36-16-14W	Vernon Oil No. 1 Barrett	Arbuckle	3,463-3,465	Mar.	90
7	Eveleigh, 11-18-14W	Cities Service No. 1 Eveleigh	Sooy	3,300-3,310	Dec.	425
8	Millard, 29-16-14W	Phillips No. 1 Brack	Arbuckle	3,462-3,480	Dec.	10
9	Roesler, 14-18-11W	Helm. & Payne No. 1 Roesler	Arbuckle	3,291-3,298	Mar.	150
10	Silica NW., 27-19-11W	Texas No. 1 Lanterman	Arbuckle	3,331-3,361	Mar.	25
	Butler County					
11	Allen, 1-26-3E	Rex Morris No. 1 "B" Allen	Miss.	2,738-2,745	Mar.	15
12	Potwin S., 18-25-4E	Branine No. 1 Joseph	Miss.	2,678-2,687	Aug.	60
	Cowley County					
13	Otter Creek, 20-33-8E	Nor. Ordnance No. 1 Raney	Lans. K. C.		Aug.	20
	Dickinson County					
14	Bonnacord, 30-14-1E	Ingling No. 1 Miller	Sand	2,483-2,485	Aug.	50
15	Lost Springs N., 34-16-4E	Hutchinson No. 1 "B" Martin	"Chat"	2,290-2,309	Mar.	125
	Ellis County					
16	Beeching, 34-15-16W	Coralena No. 1 Beeching	Lans. K. C.	3,156-3,160	Aug.	800
17	Beeching W., 33-15-16W	Coralena No. 1 Urban	Lans. K. C.	3,292-3,326	Dec.	475
18	Glathart, 16-12-19W	Coralena No. 1 Glathart	Lans. K. C.	3,504-3,514	July	275
19	Leiker, 14-15-18W	B & R Drill. No. 1 Leiker	Lans. K. C.	3,292-3,298	June	75
20	Riverview, 19-11-18W	Appleman No. 1 Richards	Arbuckle	3,610-3,619	July	1,300
	Harvey County					
21	Burrton NE., 9-23-3W	Branine No. 1 Lagree	"Chat"	3,305-3,315	Dec.	200
						MILLION CU. FT., GAS
	Leavenworth County					
22	Jarbalo, 8-10-21E	McLaughlin No. 1 Union Central	McLouth	1,251-1,274	Aug.	10
						BARRELS
	Marion County					
23	Fanska, 6-17-1E	Nelson No. 1 Fanska	"Chat"	2,672-2,683	Nov.	90
	McPherson County					
24	Paden, 10-18-1W	Adair Morton No. 1 Paden	"Chat"	2,752-2,770	Nov.	500
25	Roxbury SE., 20-17-1W	Shallow Water No. 1 Boyd	"Chat"	2,665-2,674	July	25
	Phillips County					
26	Dayton N., 13-2-19W	Allen No. 1 Skelton	Lans. K. C.	3,406-3,422	Mar.	15
27	Hansen, 14-5-20W	Cities Service No. 1 "C" Hansen	Lans. K. C.	3,300-3,312	Feb.	1,600
	Pratt County					
28	Chitwood, 23-28-12W	Lion No. 1 Chitwood	Simpson	4,396-4,399	Aug.	2,700
29	Frisbie, 5-26-13W	Stanolind No. 1 Frisbie	Lans. K. C.	3,947-3,955	June	470
	Reno County					
30	Hilger N., 34-25-4W	Phillips No. 1 Manning	Viola	4,099-4,102	Aug.	2,600
	Rice County					
31	Click, 3-18-7W	Phillips No. 1 Click	Misener	3,182-3,187	Dec.	110
32	Keller, 3-19-9W	Ackley No. 1 Keller	Sooy Conglom.	3,240-3,243	July	430
33	Volkland, 27-18-9W	Phillips No. 1 Volkland	Arbuckle	3,221-3,251	Nov.	200
	Rooks County					
34	Kriley, 22-8-18W	Continental No. 1 Kriley	Arbuckle	3,310-3,355	June	80
35	Marcotte, 15-10-20W	Champlin No. 1 Marcotte	Arbuckle	3,752-3,758	Dec.	100
36	Palco, 5-10-20W	Continental No. 1 Miller	Arbuckle	3,824-3,843	Dec.	200
						MILLION CU. FT., GAS
	Russell County					
37	Chegwidden, 29-15-11W	Mid Plains No. 1 Chegwidden	Lans. K. C.	2,998-3,007	Dec.	12
						BARRELS
38	Gustason NW., 15-15-12W	Gore No. 1 Kastrup	Lans. K. C.	3,021-3,027	Mar.	200
39	Janne, 24-15-12W	Nadel Gussman No. 1 Janne	Arbuckle	3,319-3,329	Dec.	100
40	Sellens NW., 22-15-13W	Mid Plains No. 1 Sellens	Lans. K. C.	3,039-3,050	July	150
41	Strecker, 21-15-14W	Ohio No. 1 Strecker	Arbuckle	3,342-3,345	June	75
	Saline County					
42	Hunter, 20-16-1W	Deep Rock No. 1 Hunter	"Chat"	2,681-2,683	Feb.	1,500
43	Pliny, 9-16-1W	Wolf Creek No. 1 Karber	Lans. K. C.	1,989-1,998	July	85
44	Salina, 30-14-2W	Westgate No. 1 Sudendorf	Viola	3,223-3,232	Mar.	125
	Sheridan County					
45	Studley, 23-8-26W	Union Oil No. 1 Pratt	Lans. K. C.	3,808-3,817	Mar.	175
	Stafford County					
46	Byron, 4-21-12W	Stanolind No. 1 Hewitt	Arbuckle	3,460-3,463	Aug.	400
47	Farmington, 34-24-15W	Skelly No. 1 Campbell	Arbuckle	4,417-4,433	July	3,000
48	Gates S., 3-22-13W	Bartlett No. 1 Kisner	Arbuckle	3,704-3,711	Nov.	150
49	Grunder, 11-25-15W	Cities Service No. 1 Grunder	Lans. K. C.	3,945-3,960	Mar.	50
50	Heyen, 24-22-12W	Hirshfield No. 1 Heyen	Arbuckle	3,652-3,654	Dec.	25
51	James, 16-21-12W	Faulkner No. 1 Welsh	Arbuckle	3,554-3,563	Dec.	250
52	Rothgarn, 10-21-13W	Faulkner No. 1 Rothgarn	Arbuckle	3,569-3,588	Mar.	180
53	Spangenberg, 21-22-12W	Falcon Seaboard No. 1 Spangenberg	Arbuckle	3,691-3,697	Mar.	300
54	Syms, 20-21-12W	Stanolind No. 1 Syms	Arbuckle	3,580-3,594	Dec.	100
55	Van Lieu, 20-24-13W	Stanolind No. 1 Van Lieu	Arbuckle	4,069-4,080	Mar.	1,450
56	Zenith W., 8-24-11W	Plains No. 1 Kelly	Viola	3,798-3,803	Aug.	300

In Phillips County, the drilling in and northeast of the Ray pool has confirmed predictions that this pool might become one of the major pools of western Kansas.

TABLE 2.—*Wells Drilled in Kansas in* 1943, *by Counties*

County	Oil Wells	Gas Wells	Dry Holes	Total
Barber	8	4	16	28
Barton	96		105	201
Brown			3	3
Butler	34		22	56
Chase			1	1
Clark			1	1
Cowley	27	3	42	72
Decatur			5	5
Dickinson	4		8	12
Edwards	1	1	7	9
Elk			1	1
Ellis	37		38	75
Ellsworth	26		27	53
Finney	1			1
Gove			2	2
Graham	14		24	38
Greeley			1	1
Greenwood	22		11	33
Harvey	3	2	5	12
Jefferson	11	5	11	27
Kearny		6	1	7
Kingman			6	6
Kiowa			3	3
Leavenworth	3	6	23	35
Lincoln			1	1
Logan			1	1
Lyon			2	2
Marion	31		31	62
McPherson	78		51	129
Morris			3	3
Morton			1	1
Mitchell			2	2
Ness	2		2	4
Norton			4	4
Ottawa			2	2
Osborne			3	3
Pawnee			3	3
Phillips	22		13	40
Pottawatomie			1	1
Pratt	97	1	26	124
Reno	43		25	68
Rice	69		56	125
Rooks	30		36	66
Rush	2		11	13
Russell	139		77	216
Saline	17		20	34
Scott			1	1
Sedgwick	3	1	11	15
Shawnee			1	1
Sherman			1	1
Sheridan	4			4
Stafford	72		72	144
Stevens		4		4
Sumner		1	6	7
Thomas			1	1
Trego	3		3	6
Wallace			3	3
Woodson			3	3
Totals	895	32	834	1,761

The new extension toward the northeast, called the Hansen pool, carries a great deal of promise. More than two million barrels of oil has been recovered from the subsurface in the Ray and the Hansen pools, and this is only the first flush production of these pools.

Pratt County seems destined to become one of the hot spots for 1944, for there the oil man found generous rewards for his drilling efforts during 1943. Not only were wells with large potentials drilled in the older Iuka and Carmi pools, but also large wells were drilled in the younger Stark pool and in the new Chitwood pool. In addition, important extension wells were drilled southwest of the old Cunningham pool and north of the Cairo gas pool. The great thickness of Simpson sand found in some of the wells of the pools of Pratt

TABLE 3.—*Results of Drilling in Western Kansas, Based on Type of Exploration Method*

Method	Production	Dry	Total	Percentage
Subsurface	21	82	103	20
Seismograph	11	59	70	16
Core drill	6	45	51	12
Subsurface and core drill	1	10	11	9
Seismograph and core drill	0	7	7	0
Gravimeter	0	2	2	0
Totals	41	216	257	16
Chance	5	127	132	4
Show in near-by well	2	5	7	29
Grand total	48	348	396	12

TABLE 4.—*Production of Crude Oil in Kansas for* 1943

Month	Total Number of Wells	Number of Prorated Wells	Daily Average per Prorated Well	Total Runs
January	22,401	7,220	37.1	9,182,200
February	22,438	7,234	36.8	8,686,384
March	22,469	7,251	38.4	9,730,032
April	22,548	6,746	36.3	9,580,488
May	22,548	6,749	34.6	9,080,768
June	22,567	6,689	34.6	9,003,237
July	22,615	6,708	35.4	9,068,709
August	22,698	6,173	33.4	8,914,701
September	22,728	6,144	34.2	8,835,310
October	22,792	6,209	32.2	8,525,775
November	22,828	6,246	32.1	8,666,515
December	22,889	6,299	32.4	8,435,560
Total				107,709,679

County augurs well for an ultimate high recovery per acre.

In Reno County, the highlight of the year was the liberal number of extension wells drilled in the Peace Creek pool. They have pretty well defined the limits of the probable producing area. Incidentally, drilling at the south end of the pool revealed that this large pool is but a part of the older Zenith pool of Stafford County. The two pools are now completely joined by a continuous row of good producing wells. In one of these intermediate producers, a lower producing horizon was found, and this may result in the deepening of many of the present Viola producers at a later date.

In Russell County, the oil man can always count on additional oil supplies. It still remains the rich spot of western Kansas. The large Trapp pool has now produced nearly 50 million barrels, which entitles it to rank with the major pools of the country. The Hall-Gurney and the Gorham pools, which probably will be joined in the not distant future, have produced almost as much oil, making the total for the county very impressive. The joining of the Greenvale pool with the Hall-Gurney during 1943 was one of the outstanding developments and makes the latter pool cover a large area.

Farther east in the state, Saline County suddenly jumped into the limelight when large wells were drilled in the new Hunter pool. A great deal of new exploratory drilling was compelled by this development. The results to date are not entirely inspiring. Although two other pools were found in Saline County, one old pool was revived and another new pool was found in adjoining Dickinson County, but none have the earmarks of major pools or even large pools of minor character. No doubt much more drilling will be done in Saline County during 1944 to test the possibilities of the area.

One of the very satisfying developments of the year was the discovery of oil in far-distant Sheridan County. There, the Union Oil Company of California drilled a deep test well into the Arbuckle dolomite and later plugged back to good showings in the Lansing limestone. Four wells have now been drilled in the new Studley pool and the production from them has been good. This discovery doubtless will lead to a much more hopeful attitude toward the vast undrilled acres left in western Kansas.

In Stafford County, feverish activity was encouraged by the very good results obtained in extending the Drach pool. This pool now covers an area about as large as that of the Richardson pool, the largest in the county. Consequent upon the renewed drilling activity, no less than 11 new oil spots were found in Stafford County.

Exploratory Work

More exploratory work was done in Kansas during 1943 than in any other previous year. The type of work done by seismograph involved a larger expenditure and was carried out by more companies than any other type. According to records kept by one company, 14 companies were doing seismograph work in Kansas and they averaged 10 crew months apiece. The cost of this work is estimated to have been approximately one million dollars. The greatest amount of work of this kind was carried on by the Stanolind, Texas Barnsdall and Cities Service Oil companies.

Exploration by means of the core drill was carried on by six companies. They averaged 18 core-drill months apiece. The cost of this campaign to find new structures was about one-half million dollars. Gravimeter surveys were carried on by four companies, which averaged about 6 crew months apiece. The greatest amount of core-drill work was done by the Stanolind, Skelly, and the Continental Oil companies, while in gravimeter work the Stanolind, Phillips, Ohio and Continental Oil companies were in the lead. Only one

TABLE 5.—*Producing Oil and Gas Fields in Kansas in 1943*

Line Number	Pool and Location	Discovery Year	Area, Acres	Production, Bbl.		Number Wells Producing	Producing Zone	To Top, Ft.	Thickness, Ft.
				1943	Cumulative				
	OIL POOLS OF EASTERN KANSAS								
	Butler County								
1	Augusta N., 28-27-4E	1914	1,280	116,000	13,675,350	63	Lansing Bronson Wilcox Arbuckle	1,650 1,950 2,380 2,410	15 15 10 5
2	Augusta S., 21-28-4E	1916	9,000	301,000	34,393,600	144	Lansing Bronson Marmaton Wilcox Arbuckle	1,700 2,000 2,200 2,445 2,600	12 14 15 12 7
3	Blankenship, 2-26-8E	1921	1,200	69,300	284,000	85	Bartlesville	2,650	50
4	Brandt, 15-28-7E	1936	800	158,200	954,500	50	"Chat"	2,692	8
5	Elbing, 8-23-4E	1918	1,800	304,000		74	Viola	2,530	40
6	El Dorado, 29-25-5E	1917	25,000	2,433,000	187,291,600	1,579	Admire Lansing Bronson Viola Simpson Arbuckle	600 1,700 2,000 2,500 2,510 2,550	10 20 24 5 14 6
7	Ferrell, 28-28-8E	1939	640	52,500	231,100	10	Mis. lime	2,647	42
8	Fox Bush, 25-28-5E	1917	5,000	142,000		120	Bartlesville	2,730	40
9	Garden, 32-26-6E	1928	1,600	51,000		31	Bartlesville	2,760	10
10	Haverhill, 15-27-5E	1927	900	140,000	3,616,250	69	Bartlesville	2,700	50
11	Keighley, 14-27-7E	1925	1,800	62,000		57	Bartlesville Simpson Lime	2,650 3,148	50 10
12	Kramer, 4-28-6E	1926	500	40,000		15	Viola Wilcox Arbuckle	3,050 3,020 3,040	3 15 5
13	Leon, 19-27-6E	1926	500	25,500	2,241,000	19	"Chat" Viola	2,660 3,050	50 10
14	McCullough, 1-28-6E	1929	400	35,000	456,200	7	Wilcox	3,169	6
15	Potwin, 36-24-3E	1921	4,000	200,000	6,184,000	96	Kansas City Mis. lime	2,550 2,660	5 90
16	Shaffer, 4-27-6E	1926	1,000	86,000		26	Mis. lime Viola	2,760 3,125	10 15
17	Stern, 27-27-6E	1928	700	95,400		19	"Chat" Viola	2,752 3,150	8 12
18	*Coffey County*		700	17,000	41,000	31	Peru "Chat"	1,138 1,622	12 16
	Cowley County								
19	Carson, 19-32-3E	1924	400	58,200	3,271,900	16	Layton Arbuckle	2,600 3,450	15 5
20	Darien, 33-30-4E	1939	200	47,350	271,490	5	Arbuckle	3,286	1
21	David, 35-30-4E	1935	1,100	83,000	840,000	29 1	Bartlesville Arbuckle	2,935 3,463	40 4
22	Frog Hollow, 20-32-5E	1937	900	479,000	1,581,170	48	Bartlesville	3,089	20
23	Gueda Springs, 8-34-3E	1936	600	21,000	337,950	10 1	Bartlesville "Chat"	3,150 3,320	25 21
24	Hittle, 21-31-4E	1926	2,400	792,000	4,810,300	69	Stalnaker Arbuckle	2,400 3,280	20 8
25	Rainbow Bend, 20-33-3E	1923	2,000	248,000	14,091,650	115	Burgess	3,200	50
26	Rock, 15-30-4E	1923	900	127,000	2,133,980	47	Bartlesville	2,760	45
27	State, 15-32-4E	1926	1,500	52,000		24	Layton Arbuckle	2,300 3,500	15 5
28	Wethered, 28-31-3E	1935	1,000	106,500	2,285,520	1 2 2 47	Stalnaker Kansas City Mis. lime Arbuckle	2,300 2,455 3,065 3,400	15 10 25 6
29	Winfield, 36-32-4E	1914	5,000	95,000		59	Admire Peacock Layton Bartlesville Arbuckle	600 1,400 2,300 3,100 2,500	15 17 14 20 7
30	*Elk County*		2,000	250,000	987,000	340			
	Greenwood County			3,281,150	172,607,000	2,413			
31	Atyeo-Pixlee, 6-22-10E	1923	1,000	115,000	5,020,000	92	Bartlesville	2,327	50
32	DeMalorie-Souder, 19-21-10E	1924	4,500	294,000	9,156,000	125	Bartlesville	2,150	45
33	Dunaway, 4-22-13E		1,000	51,000		44	Bartlesville	1,800	23
34	Hamilton, 26-23-11E	1929	3,000	106,000	3,388,000	89	Bartlesville	1,765	40
35	Madison, 1-22-11E	1921	3,000	142,000	7,921,000	103	Bartlesville	1,800	35
36	Quincy, 18-25-14E	1926	3,600	133,000		108	Bartlesville	1,420	36
37	Sallyeards, 17-25-9E	1921	8,000	125,000		130	Bartlesville	2,350	40
38	Seeley-Wick, 22-22-11E	1922	7,000	375,000		319	Bartlesville	1,930	45
39	Teeter, 36-22-9E	1922	4,000	240,000		194	Bartlesville	2,400	70

TABLE 5.—(*Continued*)

Line Number	Pool and Location	Discovery Year	Area, Acres	Production, Bbl.		Number Wells Producing	Producing Zone	To Top, Ft.	Thickness, Ft.
				1943	Cumulative				
40	Virgil, 13-24-12E	1916	13,000	477,000		359	Bartlesville Mis. lime	1,550 1,700	60 21
	Jefferson County								
41	McLouth, 4-10-20E	1939	600	143,000	235,000	26	McLouth Mis. lime	1,443 1,520	27
	Marion County			804,500	13,250,000	183			
42	Fanska, 6-17-1E	1943	40	1,600	1,600	1	Mis. lime	2,672	11
43	Hillsboro, 12-19-2E	1927	300	51,000	1,923,450	10	Viola	2,800	12
44	Lost Springs, 22-17-4E	1926	2,400	662,000	5,048,834	116	"Chat"	2,365	21
45	Others		8,400	91,000		60	Viola		
46	*Woodson County*		9,000	218,000		230	Mis. lime	1,575	65
	OIL POOLS OF BARBER COUNTY								
47	Bear Creek, 30-31-15W	1942	40	2,550	2,550	1	Douglas	4,235	
48	Deerhead, 22-32-15W	1942	80	4,450	4,450	2	Viola	4,950	
49	Lake City, 7-31-13W	1937	160	33,900	113,400	2 1	Simpson Arbuckle	4,530 4,607	
50	Medicine Lodge, 13-33-13W	1937	80	none	45,700	2	Misener	4,845	
51	Skinner, 29-31-14W	1943	40	none	none	1	Viola	4,626	
52	Sun City, 35-30-15W	1941	240	73,250	111,250	6	Lans. K. C.	4,344	
53	Turkey Creek, 20-30-15W	1943	40	none	none	1	Sand	4,430	
54	Whelan, 32-31-11W	1934	700	190,650	891,350	1 17	Elgin "Chat"	4,355	
	GAS POOLS OF BARBER COUNTY								
				MILLIONS CU. FT.					
55	Deerhead, 26-32-15W	1942	160			2	Viola	4,931	
56	Medicine Lodge, 13-33-13W	1927	6,000	13,721	74,821	36	"Chat"	4,455	
	OIL POOLS OF BARTON COUNTY								
				BARRELS					
57	Ainsworth, 26-16-13W	1936	5,000	561,340	3,183,670	1 1 63	Shawnee Lans. K. C. Arbuckle	2,925 3,250 3,390	
58	Ainsworth SE., 11-17-13W	1943	40	none	none	1	Arbuckle	3,358	
59	Albert, 30-18-15W	1935	1,600	170,200	968,160	16	Reagan	3,601	
60	Ames, 22-18-11W	1943	80	5,300	5,300	2	Lans. K. C.	3,042	
61	Bahr, 26-18-15W	1943	40	2,850	2,859	1	Reagan	3,495	
62	Barrett, 36-16-14W	1943	80	9,350	9,350	2	Arbuckle	3,463	
63	Beaver, 16-16-12W	1934	1,200	325,970	1,626,700	7 25 1	Oread Arbuckle Reagan	2,885 3,348 3,335	
64	Beaver NW., 6-16-12W	1942	80	16,500	17,500	1 1	Shawnee Lans. K. C.	3,066	
65	Beaver N., 4-16-12W	1937	160	16,950	251,900	3	Arbuckle	3,316	
66	Breford SW., 23-17-11W	1942	40	9,250	9,250	1	Arbuckle		
67	Bird, 33-18-15W	1940	40	2,800	12,250	1	Reagan	3,508	
68	Bloomer, 36-17-11W	1936	5,000	2,275,100	14,094,850	39 213	Lans. K. C. Arbuckle	3,044 3,257	
69	Davidson, 4-16-11W	1928	300	52,320	193,150	2 2 4	Lans. K. C. Sooy Arbuckle	3,016 3,317 3,314	
70	Eberhardt, 14-19-11W	1935	320	73,000	216,450	1 7	Lans. K. C. Arbuckle	3,194 3,311	
71	Ellinwood N., 33-19-11W	1937	80	4,650	55,550	1	Arbuckle	3,328	
72	Eveleigh, 11-18-14W	1943	40	700	700	1	Sooy	3,300	
73	Feist, 29-18-11W	1936	40	300	53,950	1	Arbuckle	3,430	
74	Feltes, 14-16-12W	1939	1,000	249,400	674,300	1 18 1	Lans. K. C. Sooy Arbuckle	3,342 3,350	
75	Hagan, 20-20-11W	1938	160	37,800	107,400	4	Arbuckle	3,323	
76	Hammer, 35-19-12W	1940	40	2,200	11,200	1	Arbuckle	3,348	
77	Harrison, 18-20-13W	1942	40	700	700	1	Arbuckle	3,498	
78	Heiser, 16-19-14W	1935	40	3,000	28,400	1	Lans. K. C.	3,228	
79	Hiss, 31-20-13W	1936	200	49,850	387,800	5	Lans. K. C.	3,270	

TABLE 5.—(*Continued*)

Line Number	Pool and Location	Discovery Year	Area, Acres	Production, Bbl. 1943	Production, Bbl. Cumulative	Number Wells Producing	Producing Zone	To Top, Ft.	Thickness, Ft.
80	Hoisington, 21-17-13W	1938	160	28,870	140,900	1 2	Lans. K. C. Arbuckle	3,222 3,440	
81	Kowalsky, 32-20-11W	1941	40	300	2,540	1	Arbuckle	3,378	
82	Kraft-Prusa, 10-17-11W	1937	17,000	4,331,000	9,875,500	9 22 110 168 2	Shawnee Lans. K. C. Gorham Arbuckle Reagan	2,885 3,160 3,335 3,281 3,310	
83	Krier, 30-16-11W	1939	Now part of the Kraft Prusa pool				Topeka Shawnee Lans. K. C. Sooy Arbuckle	2,845 2,885 3,030 3,327 3,330	
84	Lanterman, 15-19-11W	1935	500	120,150	547,100	7 5	Lans. K. C. Arbuckle	3,109 3,235	
85	Merten, 10-19-15W	1942	160	11,000	18,250	4	Reagan	3,551	
86	Millard, 29-16-14W	1943	40	none	none	1	Arbuckle	3,462	
87	Mue Tam, 35-20-11W	1942	40	6,200	11,050	1	Arbuckle	3,312	
88	Odin, 10-17-12W	1941	40	1,200	19,200	1	Arbuckle	3,340	
89	Pawnee Rock E., 17-20-15W	1941	40	2,300	11,400	1	Arbuckle	3,814	
90	Pospishel, 20-17-15W	1939	40	1,200	17,800	1	Arbuckle	3,548	
91	Rick, 1-19-11W	1936	400	60,300	406,250	7 2	Lans. K. C. Arbuckle	3,106 3,355	
92	Roesler, 14-18-11W	1943	40	6,200	6,200	1	Arbuckle	3,291	
93	Silica, 12-20-11W	1931	32,000	8,890,000	53,905,000	16	Lans. K. C. Arbuckle	2,955 3,328	
94	Silica NW., 27-19-11W	1943	40	none	none	1	Arbuckle	3,331	
	OIL AND GAS POOLS OF CLARK COUNTY								
95	Morrison (oil), 17-32-21W	1936	160	5,423	140,880	2	Viola	6,467	
96	Morrison (gas) 21-32-21W	1926	1,000	none	small	1	Sooy	5,443	
	OIL AND GAS POOLS OF EDWARDS COUNTY								
97	Belpre, 8-25-16W	1942	160	1,400	1,400	2	Lans. K. C.	3,807	5
				M CU. FT.					
98	McCarty, 31-25-17W	1929	160	30,701	158,000	1	Sooy	4,545	10
	OIL AND GAS POOLS OF ELLIS COUNTY								
				BARRELS					
99	Beeching, 34-15-16W	1943	200	8,000	8,000	5	Lans. K. C.	3,156	4
100	Beeching W., 33-15-16W	1943	40	none	none	1	Lans. K. C.	3,292	30
101	Bemis-Shutts, 16-11-17W	1935	13,000	5,066,100	26,309,100	451	Arbuckle	3,380	11
102	Blue Hill, 14-12-16W	1937	700	85,000	732,400	3 14 2	Topeka Lans. K. C. Arbuckle	3,030 3,072 3,360	5 33 6
103	Burnett, 1-11-18W	1937	5,000	5,531,400	14,959,650	2 207	Lans. K. C. Arbuckle	3,093 3,570	8 4
104	Catherine, 3-13-17W	1936	160	6,600	137,650	1	Lans. K. C.	3,262	24
105	Ellis, 31-12-20W	1942	700	59,750	59,750	15	Arbuckle	3,832	8
106	Emmeram, 4-13-16W	1937	160	33,100	138,450	4	Lans. K. C.	3,262	7
107	Glathart, 16-12-19W	1943	40	2,350	2,350	1	Lans. K. C.	3,504	10
108	Hadley, 20-11-17W	Joined to Burnett							
109	Haller, 10-11-18W	1936	40	2,740	18,350	1	Topeka	3,045	9
110	Herzog, 30-13-16W	1940	160	57,030	152,450	4	Arbuckle	3,450	8
111	High Spot, 28-12-16W	1941	40			1	Arbuckle	3,620	6
112	Koblitz, 23-12-18W	1937	800	89,500	306,700	9	Arbuckle	3,694	4
113	Kraus, 22-14-19W	1936	100	4,700	68,600	2	Sooy	3,735	5
114	Kraus NW., 17-14-19W	1942	40	1,300	1,300	1	Gorham	3,798	4
115	Leiker, 14-15-18W	1943	80	4,950	4,950	1 1	Lans. K. C. Arbuckle	3,292	4
116	Marshall, 36-11-18W	1936	1,000	398,050	1,298,300	25	Arbuckle	3,638	12
117	Penny Wann, 13-15-20W	1936	40	10,070	51,280	1	Sooy	3,653	3
118	Richards, 5-11-18W	1938	120	8,170	102,400	2	Lans. K. C.	3,332	41
119	Riverview, 19-11-18	1943	250	16,470	16,470	5	Arbuckle	3,610	9
120	Ruder, 17-15-18W	1935	700	40,200	785,300	9 2	Lans. K. C. Arbuckle	3,422 3,572	18 10
121	Solomon, 28-11-19W	1936	160	3,300	104,600	3	Arbuckle	3,629	3

TABLE 5.—(*Continued*)

Line Number	Pool and Location	Discovery Year	Area, Acres	Production, Bbl.		Number Wells Producing	Producing Zone	To Top, Ft.	Thickness, Ft.
				1943	Cumulative				
122	**Sugar Loaf, 17-13-17W**	1941	80	41,600	66,900	2	Arbuckle	3,645	9
123	Sugar Loaf SE., 28-13-17W	1941	40	8,470	20,000	1	Lans. K. C.	3,312	8
124	**Toulon, 3-14-17W**	1935	200	20,820	216,300	3 1	Lans. K. C. Arbuckle	3,298 3,512	5 45
125	**Ubert, 12-13-18W**	1936	160	15,200	192,350	3	Arbuckle	3,707	7
126	Walters, 2-12-18W	1936	1,400	542,800	2,469,250	1 37	Topeka Arbuckle	3,160 3,619	5 8
127	**Bemis S., 2-12-17W**	1938	40	11,400	47,050	1	Arbuckle	3,592	11
	OIL POOLS OF ELLSWORTH COUNTY								
128	**Breford, 7-17-10W**	1932	1,200	308,050	1,848,000	8 21	Lans. K. C. Arbuckle	3,140 3,368	12 27
129	Heiken, 25-17-10W	1930	160	1,454	32,900	2	Arbuckle	3,269	2
130	**Heiken N., 24-17-10W**	1942	80	18,975	32,775	2	Arbuckle	3,212	2
131	Lorraine, 13-17-9W	1934	5,500	395,290	9,136,400	30 55	Lans. K. C. Arbuckle	3,060 3,200	40 5
132	**Stoltenberg, 22-16-10W**	1931	8,200	2,204,100	10,698,900	1 180	Lans. K. C. Arbuckle	3,333	14
133	Stoltenberg SW., 20-16-10W	1940	320	27,550	57,600	3	Arbuckle	3,349	7
134	Wilkins, 13-17-10W	1934	3,600	865,700	3,134,600	67	Arbuckle	3,260	20
135	Wilkins SE., 32-17-9W	1942	120	53,500	73,500	3	Arbuckle	3,220	9
	OIL POOL OF FINNEY COUNTY								
136	Nunn, 27-21-34W	1938	800	27,900	173,500	3	Mississippi	4,654	10
	OIL POOLS OF GRAHAM COUNTY								
137	**Gettysburg, 7-8-23W**	1941	40	6,110	15,025	1	Lans. K. C.	3,725	30
138	**Morel, 15-9-21W**	1938	4,000	547,350	1,066,000	31	Arbuckle	3,718	12
139	Penokee, 11-8-24W	1940	40	8,350	37,150	1	Lans. K. C.	3,750	6
	OIL AND GAS POOLS OF HARVEY COUNTY								
140	Burrton NE., 9-23-3W	1943	40	none	none	1	"Chat"	3,305	10
141	Hollow-Nikkel, 30-22-3W	1931	1,500	279,950	19,433,700	68	"Chat" Hunton Simpson	3,195 3,507 3,500	13 5 14
142	**Sperling, 23-22-2W**	1935	500	49,900	441,200	5	Hunton	3,279	16
143	Stucky, 3-23-3W	1942	40	450	450	1	Mississippi	3,224	14
				M CU. FT.					
144	Sperling (gas), 23-22-2W	1935	600	21,110	6,228,110	2	"Chat"	2,955	50
				BARRELS					
145	**Halstead, 36-22-2W**	1929	1,200	76,200	1,464,450	19	"Chat"	3,005	30
	OIL POOL OF KEARNY COUNTY								
146	**Patterson, 23-22-38W**	1941	120	42,830	83,100	3	Patterson sand	4,740	4
	OIL POOL OF KINGMAN COUNTY								
147	Cunningham, 30-27-10W	1931	1,400	689,750	4,135,150	98 7	Lans. K. C. Viola	3,390 3,925	74 33
	OIL POOLS OF MCPHERSON COUNTY								
148	Bitikofer, 1-20-1W	1940	180	31,830	52,900	5	"Chat"	2,885	24
149	Bornholdt, 30-20-5W	1937	5,000	1,750,000	6,132,100	145	"Chat"	3,292	43
150	Canton N., 26-181W	1936	120	19,450	102,300	3	"Chat"	2,803	29
151	Chindberg, 18-19-2W	1929	700	59,850	1,440,450	5 22	Lans. K. C. "Chat"	2,363 3,007	19 14
152	Crowther, 26-17-1W	1942	900	192,900	197,150	16	"Chat"	2,778	12
153	Graber, 32-21-1W	1934	2,800	602,200	7,545,250	2 130	Misener Hunton	3,323 3,274	3 24

TABLE 5.—(*Continued*)

Line Number	Pool and Location	Discovery Year	Area, Acres	Production, Bbl.		Number Wells Producing	Producing Zone	To Top, Ft.	Thickness, Ft.
				1943	Cumulative				
154	Henne, 21-17-1W	1940	800	263,250	421,900	20	"Chat"	2,658	4
155	Johnson, 35-19-3W	1932	1,200	88,250	2,806,500	14	"Chat"	3,032	14
156	Lindsborg, 8-17-3W	1938	6,500	903,469	1,177,200	81 12	Viola Simpson	3,352 3,360	21 11
157	McPherson, 29-18-2W	1926	2,000	43,710	1,017,230	23	"Chat" Viola	2,967 3,140	11 6
158	Paden, 10-18-1W	1943	160	2,620	2,620	4	"Chat"	2,752	18
159	Ritz-Canton, 1-21-2W	1929	13,000	954,000	37,011,400	224	Lans. K. C. "Chat" Viola Simpson	2,360 2,935 3,412 3,440	39 31 2 4
160	Roxbury, 18-17-1W	1938	2,500	456,900	1,387,680	37	"Chat"	2,684	5
161	Roxbury S., 30-17-1W	1942	160	74,550	83,570	4	"Chat"	2,658	7
162	Roxbury SE., 20-17-1W	1943	40	1,790	1,790	1	"Chat"	2,665	9
163	Voshell, 9-21-3W	1929	3,500	639,000	24,704,000	90	"Chat" Viola Simpson Arbuckle	3,095 3,301 3,322 3,394	15 3 3 10
	OIL POOL OF NESS COUNTY								
164	Aldrich, 7-18-25W	1929	4,000	143,350	653,000	13	Mis. lime	4,428	2
	OIL POOL OF NORTON COUNTY								
165	Hewitt, 11-4-21W	1941	80	9,360	20,230	2	Lans. K. C.	3,404	3
	OIL POOLS OF PAWNEE COUNTY								
166	Pawnee Rock, 13-20-16W	1936	2,400	361,100	977,700	24	Arbuckle	3,825	16
167	Zook, 16-23-16W	1941	80	1,200	7,450	2	Arbuckle	4,066	8
	OIL POOLS OF PHILLIPS COUNTY								
168	Bow Creek, 25-5-18W	1939	40	3,950	26,180	1	Lans. K. C.	3,111	53
169	Dayton, 36-2-19W	1941	1,200	220,880	357,650	22	Lans. K. C.	3,430	8
170	Dayton N., 13-2-19W	1943	200	17,800	17,800	5	Lans. K. C.	3,406	16
171	Hansen, 14-5-20W	1943	360	27,500	27,500	1 6	Lans. K. C. Arbuckle	3,300	12 6
172	Ray, 32-5-20W	1940	3,000	1,139,725	2,083,950	9 65	Arbuckle Reagan	3,575 3,540	5 13
	OIL POOLS OF PRATT COUNTY								
173	Cairo, 7-28-11W	1939	160	13,900	76,350	3	Viola	4,267	16
174	Carmi, 29-26-12W	1942	3,000	537,900	537,900	1 68	Simpson Arbuckle	4,271	4
175	Chitwood, 23-28-12W	1943	360	14,800	14,800	7	Simpson	4,396	3
176	Frisbie, 5-26-13W	1943	120	18,650	18,650	3	Lans. K. C.	3,947	8
177	Iuka, 11-27-13W	1937	2,000	627,700	849,500	50 2	Simpson Arbuckle	4,292 4,354	7 5
178	Stark, 18-26-11W	1941	500	81,000	81,000	12	Viola	4,121	2
				M CU. FT.					
179	Cairo (gas), 7-28-11W	1935	20,000	494,135	41,500,000	35	Viola	4,278	8
	OIL AND GAS POOLS OF RENO COUNTY								
				BARRELS					
180	Abbyville, 24-24-8W	1927	1,200	23,800	481,160	9	Lans. K. C.	3,540	9
181	Buhler, 25-22-5W	1938	500	56,050	450,100	8	Simpson	3,897	5
182	Burrton, 23-23-4W	1931	5,000	1,732,550	36,913,200	396	"Chat" Hunton	3,266 3,583	42 6
183	Hilger, 16-26-4W	1934	600	377,600	2,750,700	32	Viola	4,062	5
184	Hilger N., 34-25-4W	1943	250	13,000	13,000	6	Viola	4,099	3
185	Lerado, 11-26-9W	1935	1,800	35,950	2,524,860	26	Viola	4,128	4
186	Morton, 17-24-8W	1942	40	5,200	10,400	1	Lans. K. C.	3,180	12
187	Peace Creek, 21-23-10W	1941	12,000	3,672,100	4,636,700	139	Viola	3,773	3

TABLE 5.—(*Continued*)

Line Number	Pool and Location	Discovery Year	Area, Acres	Production, Bbl. 1943	Production, Bbl. Cumulative	Number Wells Producing	Producing Zone	To Top, Ft.	Thickness, Ft.
188	Yoder, 34-24-5W	1935	500	3,500	80,825	5	"Chat"	3,450	51
				MILLIONS CU. FT.					
189	Burrton (gas), 23-23-4W	1930	5,000	6,441	56,448	52	"Chat"	3,298	70
190	Yoder (gas), 34-24-5W	1936	800	487		4	"Chat"	3,402	50
	OIL AND GAS POOLS OF RICE COUNTY								
				BARRELS					
191	Bowman, 21-19-10W	1936	250	60,421	138,350	4 2	Lans. K. C. Arbuckle	3,032 3,272	10 5
192	Brandenstein, 10-19-10W	1933	160	20,400	410,400	2	Lans. K. C.	3,014	12
193	Bredfeldt W., 12-18-10W	1939	80	3,200	34,000	2	Arbuckle	3,260	8
194	Chase, 32-19-9W	1931	8,000	7,496,300	33,653,700	23 388	Lans. K. C. Arbuckle	2,942 3,246	12 10
195	Click, 3-18-7W	1943	40	none	none	1	Misener	3,182	5
196	Doran, 13-19-10W	1936	300	55,770	228,925	7	Arbuckle	3,291	20
197	Edwards, 3-18-8W	1936	2,600	1,068,100	5,041,725	88	Arbuckle	3,278	5
198	Geneseo, 25-18-8W	1934	5,600	2,803,400	12,594,925	195	Arbuckle	3,132	14
199	Haferman, 6-19-9W	1936	800	88,140	665,460	1 9	Lans. K. C. Arbuckle	2,810 3,192	10 24
200	Heinz, 8-18-10W	1938	80	8,825	60,330	1 1	Lans. K. C. Arbuckle	3,000 3,254	19 14
201	Karber, 7-19-10W	1940	120	31,860	79,050	3	Arbuckle	3,343	7
202	Keller, 3-19-9W	1943	40	4,050	4,050	1	Sooy	3,240	3
203	Lyons, 14-20-8W	1939	40	650	11,550	1	Simpson	3,274	4
204	Orth, 27-18-10W	1932	1,000	142,160	1,033,000	1 1 15	Shawnee Lans. K. C. Pre-Camb.	 2,915 3,240	 21 3
205	Pioneer, 25-19-10W	1942	40	12,640	16,100	2	Arbuckle	3,281	5
206	Ploog, 33-18-9W	1930	500	52,160	1,365,200	9	Arbuckle	3,252	19
207	Ponce, 28-21-7W	1936	40	3,300	36,275	1	Sooy	3,388	40
208	Raymond, 21-20-10W	1929	1,200	772,330	7,775,100	24 39	Lans. K. C. Arbuckle	3,130 3,330	10 21
209	Rickard, 22-18-9W	1935	160	15,640	101,300	4	Arbuckle	3,324	41
210	Smyers, 36-19-6W	1942	1,000	271,750	404,800	23	"Chat"	3,339	25
211	Volkland, 27-18-9W	1943	300	6,775	6,775	5	Arbuckle	3,221	30
212	Welch, 2-21-6W	1924	1,500	73,700	4,441,850	22	"Chat"	3,370	44
213	Welch E., 1-21-6W	1941	80	3,120	9,950	2	"Chat"	3,341	5
214	Welch N., 23-20-6W	1937	160	6,100	57,100	3	"Chat"	3,334	32
215	Wenke, 7-20-10W	1935	500	125,900	600,900	11	Arbuckle	3,360	13
216	Wenke W., 18-20-10W	1938	80	19,465	81,385	2	Arbuckle	3,292	5
217	Wherry, 11-21-7W	1933	7,200	431,000	8,947,450	131	Sooy	3,358	22
				MILLIONS CU. FT.					
218	Lyons (gas), 35-19-8W	1888	1,509	399	11,395	1 11	Simpson Arbuckle	3,290 3,277	7 10
219	Orth (gas), 27-18-10W	1933	640	539		3	Lans. K. C.	2,906	30
220	Thurber, 22-21-9W	1937	400	2,116	10,336	7	Misener	3,317	10
	OIL POOLS OF ROOKS COUNTY								
				BARRELS					
221	Baum, 10-10-16W	1941	40	2,430	4,880	1	Lans. K. C.	3,057	15
222	Barry, 11-9-19W	1941	700	104,200	104,200	12	Arbuckle	3,435	7
223	Depita, 31-8-17W	1934	500	63,200	284,550	2 8	Lans. K. C. Arbuckle	3,212 3,409	5 10
224	Dorr, 20-9-16W	1941	160	21,000	24,275	3	Lans. K. C.	3,230	21
225	Erway, 2-10-16W	1941	40	9,200	19,790	1	Lans. K. C.	3,136	40
226	Faubion, 12-6-18W	1936	80	2,175	46,880	1	Lans. K. C.	3,128	22
227	Kriley, 22-8-18W	1943	40	1,130	1,130	1	Arbuckle	3,310	45
228	Kruse, 3-10-16W	1928	40	1,550	10,335	1	Lans. K. C.	3,115	6
229	Laton, 11-9-16W	1927	1,300	410,000	2,136,300	87	Lans. K. C.	3,228	33
230	Marcotte, 15-10-20W	1943	40	none	none	1	Arbuckle	3,752	6
231	Palco, 5-10-20W	1943	40	none	none	1	Arbuckle	3,824	19
232	Ray SE., 9-6-20W	1941	40	10,400	18,775	1	Reagan	3,600	6
233	Stockton, 35-7-17W	1937	80		26,400	1	Lans. K. C.	3,180	62
234	Webster, 21-8-19W	1930	40		56,369	1	Arbuckle	3,434	1
235	Westhusin, 11-9-17W	1936	700	143,000	667,700	15	Lans. K. C.	3,231	11
236	Zurich, 26-10-19W	1934	200	12,600	141,050	3	Lans. K. C.	3,340	9

TABLE 5.—(*Continued*)

Line Number	Pool and Location	Discovery Year	Area, Acres	Production, Bbl.		Number Wells Producing	Producing Zone	To Top, Ft.	Thickness, Ft.
				1943	Cumulative				
	Oil and Gas Pools of Rush County								
237	Otis, 10-18-16W	1934	1,200	326,100	2,232,775	24	Reagan	3,527	9
238	Winget, 15-16-16W	1936	120	1,200	50,200	1	Lans. K. C.	3,243	4
				Million Cu. Ft.					
239	Otis (gas), 11-18-16W	1930	15,000	13,340	87,530	57	Reagan	3,507	2
	Oil Pools of Russell County								
				Barrels					
240	Atherton, 30-13-14W	1935	1,900	179,850	1,461,275	7	Lans. K. C.	3,008	47
						28	Arbuckle	3,284	5
241	Big Creek, 36-14-15W	1935	2,600	437,000	3,993,350	4	Lans. K. C.	2,908	42
						40	Gorham	3,152	5
						21	Arbuckle	3,171	5
242	Big Creek E., 31-14-14W	1938	700	91,800	392,820	7	Lans. K. C.	3,180	15
						4	Arbuckle	3,149	4
243	Boxberger, 36-15-15W	1935	160	11,000	165,750	3	Lans. K. C.	3,147	4
244	Bunker Hill, 31-13-12W	1935	200	1,000	74,825	3	Lans. K. C.	2,965	16
245	Chegwidden, 29-15-11W	1943	40	none	none	1	Lans. K. C.	2,998	9
246	Donovan, 10-15-15W	1935	200	22,800	105,600	4	Lans. K. C.	3,193	7
247	Driscoll, 30-15-11W	1940	160	7,700	31,775	3	Arbuckle	3,255	5
248	Dubuque, 34-15-12W	1935	300	52,700	283,800	2	Lans. K. C.	3,275	3
						4	Arbuckle	3,330	5
249	Eichman, 24-15-14W	1935	800	16,000	695,100	7	Arbuckle	3,316	10
250	Fairfield, 22-15-13W	1938	40	2,500	12,650	1	Arbuckle	3,352	5
251	Fairport, 8-12-15W	1923	3,600	636,100	16,265,200	143	Lans. K. C.	2,950	12
							Gorham	3,211	5
252	Forest Hill, 29-15-12W	1941	800	97,000	155,400	16	Arbuckle	3,320	3
253	Gideon, 8-15-14W	1930	40	2,400	44,800	1	Sooy	3,266	7
254	Gorham, 5-14-15W	1926	8,500	1,558,200	24,718,875	1	Tarkio	2,525	25
						8	Topeka	2,765	15
						125	Lans. K. C.	3,027	30
						11	Arbuckle	3,289	4
						160	Reagan	3,299	1
255	Gustafson, 14-15-12W	1941	160	19,520	33,820	3	Lans. K. C.	3,050	12
						1	Arbuckle	3,344	5
256	Gustafson NW., 15-15-12W	1943	160	15,000	15,000	2	Lans. K. C.	3,021	6
						2	Arbuckle	3,322	5
257	Hall-Gurney, 30-14-13W	1931	25,000	4,472,300	18,963,950	1	Wabaunsee		
						4	Topeka	2,675	12
						406	Lans. K. C.	2,985	15
						24	Gorham	3,165	4
						79	Arbuckle	3,451	3
						18	Reagan	3,129	1
						2	Pre Camb.	3,156	25
258	Janne, 24-15-12W	1943	40	none	none	1	Arbuckle	3,319	10
259	Jerry, 4-15-14W	1942	40	10,600	10,600	1	Lans. K. C.	2,985	20
260	Lewis, 28-14-12W	1940	40	1,600	10,283	1	Wabaunsee	2,317	12
261	Mahoney, 8-14-12W	1940	120	4,700	36,380	3	Lans. K. C.	2,977	3
262	Mobl, 18-14-13W	1941	40	1,900	5,520	1	Reagan	3,253	5
263	Rusch, 29-14-14W	1941	250	74,500	168,800	2	Lans. K. C.	3,071	12
						5	Arbuckle	3,216	8
264	Russell, 22-13-14W	1934	1,200	382,800	5,619,300	3	Lans. K. C.	3,195	9
						45	Arbuckle	3,280	6
265	Russell N., 15-13-14W	1942	40	10,660	13,780	1	Lans. K. C.	2,978	30
266	Sellens, 26-15-13W	1929	1,300	198,900	2,959,475	1	Shawnee		
						15	Lans. K. C.	3,088	9
						15	Arbuckle	3,352	13
267	Steinert, 21-15-15W	1936	40			1	Lans. K. C.	3,060	36
268	Strecker, 21-15-14W	1943	40	5,050	5,050	1	Arbuckle	3,342	3
269	Trapp, 23-15-14W	1939	32,000	10,895,350	46,116,275	4	Shawnee	2,889	7
						137	Lans. K. C.	3,062	2
						762	Arbuckle	3,252	3
270	Vaughn, 17-14-14W	1937	1,100	344,900	1,164,725	26	Lans. K. C.	3,004	30
						1	Gorham	3,282	7
						8	Arbuckle	3,341	5
271	Williamson, 9-14-14W	1936	1,200	166,500	233,170	2	Tarkio	2,522	28
						29	Lans. K. C.	3,009	22

TABLE 5.—(*Continued*)

Line Number	Pool and Location	Discovery Year	Area, Acres	Production, Bbl.		Number Wells Producing	Producing Zone	To Top, Ft.	Thickness, Ft.
				1943	Cumulative				
	OIL POOLS OF SALINE COUNTY								
272	Hunter, 20-16-1W	1943	600	62,850	62,850	14	"Chat"	2,681	2
273	Olsson, 10-16-3W	1929	80	650	2,050	1	Maquoketa	3,303	12
274	Pliny, 9-16-1W	1943	40	4,150	4,150	1	Lans. K. C.	1,989	9
275	Salina, 30-14-2W	1943	40	7,100	7,100	1	Maquoketa	3,223	9
	OIL POOL OF SCOTT COUNTY								
276	Shallow Water, 15-20-33W	1934	600	274,050	1,426,625	9	Mis. lime	4,670	16
	OIL POOLS OF SEDGWICK COUNTY								
277	Cross, 29-25-1W	1929	160	4,500	55,900	2	Lans. K. C.	2,690	40
278	Eastborough, 19-27-2E	1929	1,000	130,000	8,338,700	39	"Chat" Viola	2,956 3,238	14 4
279	Goodrich, 16-25-1E	1928	640	272,266	3,469,625	31	Lans. K. C. "Chat" Misener	2,614 3,010 3,334	2 10 3
280	Greenwich, 14-26-2E	1929	700	190,000	9,715,690	41	"Chat" Viola Simpson	2,885 3,321 3,350	3 5 4
281	Kuske, 24-25-1E	1929	40	2,200	143,680	1	Sooy	3,013	2
282	Robbins, 20-28-1E	1929	420	73,650	3,114,450	50	Mis. lime	3,090	12
283	Valley Center, 1-28-1W	1928	1,500	274,950	20,820,000	65	Misener Viola	3,368 3,366	7 2
	OIL POOL OF SHERIDAN COUNTY								
284	Studley, 23-8-26W	1943	160	30,090	30,090	4	Lans. K. C.	3,808	9
	OIL POOLS OF STAFFORD COUNTY								
285	Ahnert, 26-22-13W	1941	40	1,300	15,700	1	Arbuckle	3,784	4
286	Bedford, 21-23-12W	1940	850	229,700	704,675	21	Arbuckle	3,859	9
287	Byron, 4-21-12W	1943	40	2,000	2,000	1	Arbuckle	3,460	3
288	Curtis, 6-22-13W	1942	80	32,900	36,100	2	Arbuckle	3,693	7
289	Drach, 12-22-13W	1937	2,200	314,160	728,660	38	Arbuckle	3,693	12
290	Farmington, 34-24-15W	1943	160	24,375	24,375	4	Arbuckle	4,417	16
291	Fischer, 31-21-12W	1938	120	73,400	174,250	3	Arbuckle	3,641	7
292	Gates, 27-21-13W	1933	700	135,150	947,000	13	Arbuckle	3,679	39
293	Gates S., 3-22-13W	1943	40	435	435	1	Arbuckle	3,704	7
294	Grunder, 11-25-15W	1943	40	3,550	3,550	1	Lans. K. C.	3,945	15
295	Hazel, 21-21-13W	1942	160	44,300	59,050	4	Arbuckle	3,692	9
296	Heyen, 24-22-12W	1943	40	none	none	1	Arbuckle	3,652	2
297	James, 18-21-12W	1943	40	none	none	1	Arbuckle	3,554	9
298	Jordan, 15-25-14W	1936	260	68,050	428,460	7	Lans. K. C.	3,722	5
299	Kipp, 27-25-14W	1937	300	99,450	326,425	11	Lans. K. C.	3,827	79
300	Leesburgh, 12-25-13W	1938	600	437,600	1,013,950	16	Arbuckle	4,153	10
301	Macksville, 3-24-15W	1941	80	3,000	29,430	2	Lans. K. C.	3,811	16
302	Max, 35-21-12W	1938	500	149,100	399,060	2 9	Lans. K. C. Arbuckle	3,356 3,570	16 5
303	Rattlesnake, 13-24-14W	1938	40	9,290	51,550	1	Lans. K. C.	3,608	48
304	Richardson, 36-22-12W	1930	1,200	724,100	5,781,200	59	Arbuckle	3,537	62
305	Riley, 28-23-11W	1940	120	13,850	38,250	3	Lans. K. C.	3,323	5
306	Rothgarn, 10-21-13W	1943	120	12,670	12,670	3	Arbuckle	3,569	19
307	Shaeffer, 3-12-13W	1941	300	52,500	176,714	5 1	Lans. K. C. Arbuckle	3,404 3,546	4 4
308	St. John, 23-24-13W	1935	1,200	281,200	1,546,100	15 10	Lans. K. C. Arbuckle	3,588 4,075	32 12
309	Sittner, 33-21-12W	1937	800	61,200	461,150	2 9	Lans. K. C. Arbuckle	3,278 3,600	36 6
310	Sittner S., 3-22-12W	1938	650	3,100	778,550	19	Arbuckle	3,501	6
311	Snider, 3-21-11W	1936	320	27,600	249,800	4 1 1	Lans. K. C. Simpson Arbuckle	3,111 3,362 3,324	38 6 18
312	Snider S., 16-21-11W	1938	360	98,775	321,725	8	Simpson	3,402	7
313	Spangenberg, 21-22-12W	1943	40	8,900	8,900	1	Arbuckle	3,691	6
314	Stafford, 15-24-12W	1940	600	501,420	1,106,300	20 1	Viola Arbuckle	3,836 3,945	14 10

TABLE 5.—(*Continued*)

Line Number	Pool and Location	Discovery Year	Area, Acres	Production, Bbl. 1943	Production, Bbl. Cumulative	Number Wells Producing	Producing Zone	To Top, Ft.	Thickness, Ft.
315	Syms, 20-21-12W	1943	40	none	none	1	Arbuckle	3,580	14
316	Van Lieu, 20-24-13W	1943	120	41,050	41,050	3	Arbuckle	4,069	11
317	Zenith, 23-24-11W	1937	5,600	3,790,900	14,137,150	352	Misener	3,804	20
							Viola	3,860	5
318	Zenith W., 8-24-11W	1943	40	6,760	6,760	1	Viola	3,798	5
	HUGOTON GAS POOL OF STEVENS COUNTY								
				MILLION CU. FT.					
319	Hugoton, 3-35-34W	1922	2,000,000	63,354	362,000	340	Winfield	2,755	10
							Ft. Riley	2,800	8
							Florence	2,850	10
	OIL AND GAS POOLS OF SUMNER COUNTY								
				BARRELS					
320	Anness, 2-30-4E	1937	40	13,250	67,100	1	Simpson	4,394	7
321	Caldwell, 17-35-3W	1929	200	53,800	1,134,500	4	Simpson	4,765	19
322	Churchill, 25-31-2E	1926	1,000	116,200	18,732,500	59	Stalnaker	1,820	25
323	Latta, 9-30-2W	1927	400	85,000	839,800	12	Lans. K. C.	3,042	14
324	Oxford, 25-32-2E	1927	800	175,800	14,866,500	43	Stalnaker	2,020	16
							Layton	2,510	20
							Arbuckle	2,890	5
325	Oxford W., 17-32-2E	1926	160	11,850	524,725	3	Arbuckle		
326	Padgett, 23-34-2E	1924	1,800	75,000	2,076,000	20	Mis. lime	3,474	28
327	Rainbow Bend W., 24-33-2E	1926	160	10,000	420,800	1	Burbank		
						1	Arbuckle		
328	Rutter, 21-33-2E	1926	80	7,200	74,700	2	Mis. lime	3,315	27
329	Vernon N., 15-35-2E	1915	500			11	Mis. lime	3,443	22
330	Wellington, 33-31-1W	1929	1,200	206,600	5,264,350	96	"Chat"	3,655	11
331	Zyba, 7-30-1E	1937	80	6,300	32,600	1	Simpson	3,866	3
				THOUSAND CU. FT.					
332	Wellington (gas), 33-31-1W	1929	1,200	310,125		45	"Chat"	3,655	12
	OIL POOLS OF TREGO COUNTY								
				BARRELS					
333	Wakeeney, 14-11-23W	1934	640	42,000	513,220	6	Lans. K. C.	3,619	8

magnetometer party was in the field during the year. It was operated by the Stanolind Oil Co. for a total of nine crew months.

ACKNOWLEDGMENTS

The data in this report could not have been compiled without the generous cooperation of many geologists of Wichita and Kansas. Those who contributed information of great value are Paul Harper, James Dougherty, Edward Koester, Robert Meyer, Harold Smedley, Virgil Cole, William Imbt, Frank Brooks, and George F. Berry. The reports of the Conservation Division of the Kansas Corporation Commission were extremely helpful.

Oil and Gas Development in Kentucky during 1943

By Louise Barton Freeman* and Coleman D. Hunter†

The total production of oil in Kentucky during the year 1943 reached 7,010,776 bbl., which is more than at any time since 1930. Of this total, 5,287,659 bbl. was produced from the counties west of the Cincinnati arch, 692,359 bbl. from the 18 new pools opened during the year, and 3,260,765 from the Smith Mills pool, which was discovered in August of 1942. This is an important increase in western Kentucky in spite of the low price of crude, and demonstrates effectively the desire of the industry to cooperate in meeting the increased demands made by the war.

Western Kentucky

Two deep tests were drilled in the Kentucky portion of the Mississippi Embayment this year. Both were drilled to test the St. Peter. One well, drilled in Marshall County by the Adams Oil and Gas Co., did not encounter any St. Peter sandstone but drilled 650 ft. of formation below the position of the St. Peter and above the true Knox dolomite. The other well, in Ballard County, was reported to have tested the St. Peter and to have been temporarily abandoned at 3069 ft. At this depth the well probably was stopped in about the same formation as the Marshall County well. No accurate information is available on the Ballard County well.

Several new producing areas were added to the list of fields in the western Kentucky coal basin, in Daviess, Henderson, McLean, Ohio, Union and Webster Counties. The Smith Mills pool was enlarged and production was found in the McClosky (Ste. Genevieve) in addition to the Cypress sandstone from which much of the earlier production had been obtained.

There was some interest during the year in testing the Devonian and Silurian formations in the area south and east of the western Kentucky coal basin. In the fall of 1943, a 15 to 20-bbl. well was drilled in Allen County and two more wells are now being drilled. The production was obtained from within a few feet of the base of the Chattanooga black shale, probably in the upper Silurian.

One well in Simpson County was drilled completely through the Silurian section before it was abandoned. Several wells were drilled in Logan, Todd and Christian Counties to test the Devonian where it is thinned by removal of the upper formations before deposition of the Chattanooga shale. None of these wells was successful but several other locations are now being tested. The Silurian thins in like manner on the eastern flank of the coal basin as the crest of the Cincinnati arch is approached, and it is along this thinning edge that such fields as the LeGrande, Logsdon Valley, Magnolia, Bowling Green and the Barren County pools were developed. A number of wells were drilled around these old pools in an effort to extend them, some of which were successful. The wells listed this year in Larue, Hardin, Barren, Hart and Warren Counties were drilled in the search for other such fields.

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TABLE 1.—*Oil and Gas Production in Kentucky*

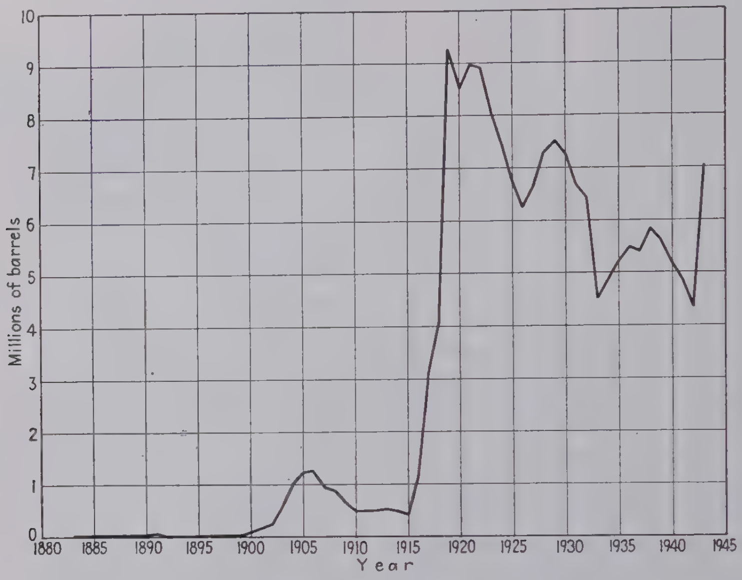
Line Number	County	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
1	Allen	1866		6,353,471	63,772			x	4	2
2	Ballard			none	none			x	1	1
3	Barren	1919		2,723,585	18,331			x	10	8
4	Breckinridge	1921		4,460	1,121			x	1	1
5	Butler	1937		193,117	24,556			x	25	8
6	Casey			none	none			x	1	1
7	Christian			none	none			x	3	3
8	Clay	1900		none	none	x	x	97	5	1
9	Clinton	1921		30,873	19,637			104	20	5
10	Crittenden			none	none				1	1
11	Cumberland	1919		368,926	4,400	x	x	x	4	2
12	Daviess	1919		10,680,987	538,193		5,900,000	x	63	36
13	Edmonson			none	none			x	2	2
14	Elliott	1917		110,580	6,677			x	6	2
15	Estill	1918		12,055,143	328,076			x	44	3
16	Floyd	1940		383,224	14,388			1,540	32	5
17	Grayson			none	none			x	1	1
18	Hancock	1930		3,295,796	141,643			x	13	10
19	Hardin			none	none			x	2	2
20	Hart	1920		6,509,945	37,299			x	x	x
21	Henderson	1931		6,058,617	2,812,023			x	169	79
22	Hopkins	1920		81,296	none			x	2	2
23	Jackson	1919		15,489	none			36	12	2
24	Johnson	1919		2,584,450	275,055			x	12	4
25	Knott	1906		45,733	none			463	36	5
26	Knox	1929		none	none			x	2	
27	Larue			none	none			x	2	2
28	Lawrence	1913		8,670,669	162,081			x	1	1
29	Lee	1918		40,578,997	454,174			x	x	x
30	Lewis			none	none			x	3	3
31	Lincoln			13,253	x			x	6	2
32	Logan	1918		12,218	295			x	4	4
33	McCreary	1909		115,804	1,262			x	3	3
34	McLean	1919		4,882,903	212,015			x	12	11
35	Magoffin	1920		11,836,476	218,882			1,087	7	1
36	Marshall			none	none			x	1	1
37	Martin	1898		503,258	54,578			477	31	4
38	Menifee	1902		246,741	6,316	x	x	x	19	6
39	Metcalfe	1932		42,524	1,495			x	1	1
40	Morgan			131,133	none			x	2	2
41	Muhlenberg	1929		347,497	8,066			x	2	2
42	Ohio	1919		22,710,219	588,386			x	17	10
43	Owsley	1920		129,640	2,085				0	0
44	Pike	1931		1,706	1,706			530	97	21
45	Powell	1918		4,667,225	110,983	x	x	x	x	x
46	Rowan			none	none			x	10	10
47	Russell			none	none			x	2	2
48	Simpson	1921		156,746	932			x	2	2
49	Taylor			none	none			x	1	1
50	Todd			none	none			x	4	4
51	Union	1942		820,443	721,183			x	89	32
52	Warren	1918		6,742,116	57,218			x	8	5
53	Wayne	1898		2,224,143	46,217			202	2	1
54	Webster	1938		114,343	61,131	x	x	x	30	18
55	Wolfe	1912		1,211,270	16,597			x	6	3
56				157,655,018	7,010,776				828	335

[b] Footnotes to column heads and explanation of symbols are given on page 270.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested. to End of 1943	
	Oil													
	Flowing	Artificial Lift	Gas		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
1		2					"Corniferous," Sil	D	Por	300	20	MC	Brassfield Silurian	540
2													Lower Ordovician	3,069
3		2					Louisville and Laurel, Sil	D	Por	500		MC	Brassfield	600
4												MC	Silurian	1,534
5		17					Tar Springs, Hardinsburg, Jackson, MisU	S	Por	400–540		AM	Cypress	550
6												MU	Trenton	567
7							Aux Vases, MisU	S	Por	1,035	8	MU	Trenton	
8			4				"Corniferous," Sil	D, SD	15	1,000 1,600	30	MU	Silurian	1,700
9		10	5				Trenton and Knox, Ord. M & L	L, D	Cav	400 1,837	30	H, MU	Knox	1,845
10														1,250
11			2				Trenton, OrdM	L	Cav	400		H	Lower Ordovician	835
12		23	4				Jackson, Bethel, Cunningham, McClosky, MisU	S, OL	Por			AF	Mississippian	
13							Mid. Devonian, Dev.	L	Por	1,300		MU	Silurian (top)	1,370
14		4					Wier, MisL	S	Por	900		AF	Knox, L. Ord.	4,191
15		41	0	2			"Corniferous," Sil	D, SD	15	800	30	MU	Knox, L. Ord.	2,640
16			27				Pen, Maxon, "Big Lime," "Big Injun" Pen MisU	S, L	Por	900-3,100		MC	Silurian	3,643
17												MU	Silurian	1,524
18		3					Tar Springs, MisU	S	Por	450-500			McClosky and Silurian	1,900
19													Silurian	986
20							"Corniferous" "Blue Sand," Sil	D	Por	500-1,000		MC	Lower Ordovician	1,920
21		90					Pen. Waltersburg, Tar Springs, Hardinsburg, McClosky Pen MisU	S, OL	Por	1,800–1,900		AF	Devonian	4,700
22							McClosky, MisL	OL	20	2,400			Devonian	4,927
23		3	7				"Corniferous," Sil	D, SD	20	1,100		MU	Silurian	1,200
24			8				"Big Six," Sil	S	Por	2,380	40	MC	Silurian	2,430
25			31				Pen, Maxon, "Big Lime," "Big Injun" Blackshale Pen MisL & U	S, L, D, LS, H	Por	1,250–3,000		MC	Upper Ordovician	3,706
26			2				"Corniferous," Sil	D, DS	15–20	650–1,150	30	MU	Lower Ordovician	5,000
27							Silurian	D	Por	920		MU	Trenton	1,380
28							Wier, MisL	S	Por	900			Silurian	4,975
29							Corniferous, Sil	D, DS	15	825–1,250	70–100	MU	Lower Ordovician	3,527
30							Corniferous, Sil	D, DS			700	MU	Silurian	700
31		4					Ord. U.	D		130	20	MU	Ordovician Knox	1,680
32							Devonian and Silurian	L, D		1,200		MU	Silurian	1,450
33							Beaver, Sunnybrook MisL Ord. M	L	Por Cav	750–1,200			Lower Ordovician	2,515
34		1					Tar Springs, MisU	S	Por	1,600			McClosky	2,000
35			6				Pen, Maxon, Big Lime, Black Shale Pen MisL	S, L, H	Por	800–4,000	10–800		Ordovician	5,343
36													Lower Ordovician	3,182
37			27				Pen, Maxon, Big Lime, Black Shale Pen MisU MisL	S, L, H	Por	700–3,000	10–600		Silurian	3,325
38		7	6				Corniferous, Sil	D, DS	Por	500–1,230		MU	Ordovician	
39												MU	Knox-L. Ord.	1,785
40							Salt Sand, Pen	S	Por				Silurian	2,030
41							Hardinsburg, MisU	S	Por			A	Silurian	5,065
42		7					Tar Springs, McClosky, MisU	S, OL	Por			A	Silurian	2,505
43							Big Lime, MisU	L	Por	1,100	15	MU	Silurian	1,962
44		1	75				Pen, Maxon, Big Lime, Black Shale Pen MisU, MisL	S, L, H	Pcr	800–4,000	10–800		Ordovician	5,343
45							Corniferous, Sil	D, DS	Por	15	30	MU	Silurian	900
46							Corniferous, Sil	D, DS	Por			MU	Brassfield, L. Silurian	1,040
47							Sunnybrook, OrdU	L	Cav			H	Trenton	630
48							Corniferous, Sil	D	Por			MU	Brassfield	745
49							Corniferous, Blue Sand, Sil	D	Por	600		MU	Silurian	650
50							Pen, Waltersburg, Tar, Springs Cunningham, McClosky Pen Mis	S, OL	Por	800–2,860		MU A	Silurian Upper Mississippian	1,862 2,955
51		57												
52		3					Brownsport, Jeffersonville SilU Dev. M	L, D	Por	500–1,000	20	MU	Knox, L. Ord.	2,870
53			1				Beaver, MisL	L	Cav	400–500		MC	Lower Ordovician	1,810
54		11	1				Pen, Cypress McClosky Pen MisU	S, OL	Por	2,200–2,400		AF	Devonian	3,217
55			3				Corniferous, Sil	D, DS	Por	1,270–1,380		MU	Lower Ordovician	3,785
56		283	210											

In the spring of 1943 a lease play was started in a wide strip extending northwest from Bowling Green through northern Warren County, Butler and Ohio Counties.



Annual production of petroleum in Kentucky, 1883 to 1943.

The play was started by the Carter Oil Co., but other companies and independent operators moved in immediately. However, none of this territory has thus far been tested and no clue as to what started the excitement has been released. This strip is roughly along the strike of thinning Devonian but the thinning in this instance is due to overlap of younger formations rather than to the removal of younger formations by erosion. A few wells have been drilled in Butler County in the south end of the area in question by individual operators who found some shallow production in the Chester.

Another lease play was started in a strip about five miles wide along the Ohio River Valley from Daviess to Breckinridge Counties.

Southern Kentucky

There was considerable activity during the year, mainly by independent operators, in southern Kentucky, in the saddle between the Jessamine and Nashville domes on the Cincinnati arch. A number of wells were drilled in Cumberland, Clinton, Russell and Wayne Counties. The wells in Wayne County were drilled for the purpose of repressuring production from the "Beaver sand," which is a local development of limestone just above the Chattanooga black shale. The wells in Clinton and Cumberland Counties were drilled to test the Ordovician "pays" variously known as Upper and Lower Sunnybrook and Granville. One well in Clinton County was drilled to the "Beech Bottom," which is a porous zone in the upper portion of the Knox dolomite. This gave small production in an area from which a little oil was produced years ago.

Eastern Kentucky

In the summer of 1943 the Gulf Oil Co., with something like 70,000 acres under lease in Rowan and southern Lewis Counties, drilled 13 wells for the purpose of testing the so-called "Corniferous" (Niagaran dolomites and dolomitic sandstones) in a position on the Cincinnati arch similar to that occupied by the Big Sinking pool to the south. No oil was found other than showings in most of the wells. Several were drilled through the Brassfield to see whether or not this formation, which often is saturated at the outcrop, might produce downdip. The percentage of sand to dolomite and the thickness of the formation varied very little in the entire area tested.

The redevelopment of the old Mariba-Denniston and Ragland oil fields of Menifee County, which was started in 1942, became important in August of 1943 when production was increased from 75 bbl. to 1500 bbl. per month. This is heavy black oil, good only for Diesel and fuel oils. War conditions have made it profitable for the refineries to handle such oil. Probably there will be an increase in production from this area during 1944, as the limits of the field are not yet known.

When the deep Knox test was drilled in Elliott County on the Burkes dome, a zone capable of producing 2½ bbl. of oil was encountered in the Weir sand. The drillers acquired this well and drilled another to the Weir about 100 ft. from it. They shot this well, which usually is the key to Weir production, and it is now producing naturally 25 to 30 bbl. per day. Four other wells and two dry holes have been drilled since. The four producing

TABLE 2.—*Summary of Drilling Operations in Western Kentucky in 1943*

County	Pool	Location	Discovery Date	Estimated Producing Acres	Number of Wells	Abandoned	Daily Average, Bbl.	Total for 1943, Bbl.	Accumulated Production, Bbl.
Daviess	Birk City	P-27	4-13-38	2,748	104	7	369	128,607	2,330,013
	Panther	11-N-27	6-2-43		4		206	18,923	29,699
	Thurston	9, 11-P-20	5-6-39		2		3	1,119	21,951
Henderson	Birk City (See Daviess)								
	Cairo	17-0-23	6-30-43		1		25	3,075	3,075
	Corydon	18, 19-P-22	3-1-39		5		47	9,643	175,277
	Geneva	16-Q-22	12-20-43		4		298	9,240	11,692
	Gilmore	25-P-27	8-27-38	398	9		100	36,662	149,424
	Greenbriar	24-O-24	7-14-43		1		28	2,624	2,624
	Hebbardsville	18, 23-P-26	8-24-40		13		82	27,180	157,129
	Poole	2, 3, 8, 9-N-23 14-N-24	6-2-43		14		334	72,520	82,453
	Reed	11, 19, 20-Q-26	5-17-39	92	5		64	24,127	45,119
	Robard	21, 22-O-23	2-17-43		9		200	70,440	79,957
	Smith Mills	3-P-21 23, 24-Q-21	8-19-42		81		8,936	3,260,765	3,395,200
	South Reed	5-P-26	11-13-40		1		0		864
	Spottsville	22-Q-25	8-9-39		4		45	16,407	141,595
	Zion	25-P-25	2-17-43		1		5	1,183	2,708
McLean	Livermore (McClosky)	6-L-29	3-22-39		5		91	33,265	145,141
	North Livermore	24-M-29	5-1-43		1		31	3,021	5,797
Muhlenberg	Belton	21-I-30	2-1-39		3		14	4,750	50,270
Ohio	Barnett Creek	13-M-31	10-27-43		1		8	241	241
Union	Cairo (See Henderson)								
	Chapman	3-O-20	12-29-43		1		17	524	524
	Hitesville	4-0-21 24-P-21	7-7-43		9		264	48,498	48,498
	Morgan field	12, 13-O-19	5-19-43		6		247	53,004	55,939
	Raleigh	13-O-18	10-27-43		2		55	5,373	5,373
	St. Vincent	9, 12-O-20	6-30-43		17		1,669	356,750	356,750
	Spring Grove	20-O-18	11-19-41		10		111	41,459	86,731
	Tilden (Abandoned)	13-N-22	1-7-42		2	2	1	140	565
	Uniontown	16-P-20 20-P-19	11-11-42		22		541	196,375	214,488
	Utley	16-P-21	2-24-43		2		59	18,841	18,841
	Wabash Island	12-P-18	10-7-42		1		4	965	2,188
	Wathen	1, 6, 10-O-19	6-10-42		8		162	63,422	121,960
Webster	Clay	23-M-21	9-29-43		2		18	1,671	1,671
	East Poole	10-N-23	7-14-43		1		13	2,375	2,704
	Pratt	14-N-24	7-21-43		4		157	24,056	24,056
	Sebree	22-N-24	12-21-38		7		50	18,208	58,437
	Totals				355		14,254	4,568,880	7,995,884

wells are now making 8 to 15 bbl. per day. During the next year, undoubtedly there will be an extensive development program because in the last five or six months more than 80 per cent of the acreage available has been acquired by minor and major operators. This area is on the same Paint Creek uplift on which are located the Magoffin and Johnson Counties fields that have produced oil since 1918. It has yet to be proved whether the fault to the north, which has 62 ft. of displacement, will have any effect upon production. Many operators think production will be encountered on the north side of the fault as well as on the downthrown side. However, no wells have yet been drilled north of the fault.

In Jackson County, the area downdip from the gas field is being tested for oil and is being watched with great interest. At the end of 1943 five wells had been drilled, three of them oil wells capable of producing 50 to 75 bbl. per day. This production is obtained from the thinning Niagaran dolomites ("Corniferous"). The area is being further developed and it is probable that Jackson County and Elliott County will be outstanding for new oil plays in eastern Kentucky next year.

Of the 3250 wells that have been drilled in the Big Sandy gas field, only 346 were dry holes. This does not include the Weir and Corniferous production of Johnson, Magoffin, Morgan, Breathitt, Clay and Knox Counties. The average production, including the dry holes, was more than 600,000 cu. ft. per well. The producing formations are

	PER CENT
Salt sands, Pennsylvanian	6.8
Maxon sand, Mauch Chunk	11.2
Big Lime, Mississippian	6.7
Black shale, Devono-Mississippian	61.9
Dry holes	10.5
Miscellaneous (including Big Six, Big Injun and Berea)	3.0

Eighteen wells have now been drilled on the head of Red River in Wolfe County. Nine of these are producing from the Salt sand an average of 300,000 cu. ft. at 85 lb. rock pressure. The areal limits of this field have not yet been defined and with additional development undoubtedly a market will be provided during the next year.

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Petroleum Production in Louisiana for 1943

By J. Huner, Jr.,* L. C. Aycock,† and P. M. Lyons†

In view of the unfavorable discovery trend that has set in during the past few years, it seems permissible to infer that the large, more easily found crude reserves in Louisiana are now known. Without doubt, many new producing areas will be located, but in the light of development during the past few years the majority of new areas probably will be found at greater depths and from relatively poorer sands.‡

Although sufficient reserves exist in Louisiana to last at the present rate of production for a considerable period, additional reserves must be found in more intensive development of the presently known structures. In order to ensure the greatest ultimate recovery from such structures, the most advanced technical methods must be employed in their exploitation. Wherever possible, cycling and repressuring plants should be installed. There are presently in Louisiana, especially in south Louisiana, a great many fields that contain gas-condensate reservoirs. These reservoirs cannot be produced for their liquid hydrocarbon content under present conditions without wasting an enormous quantity of gas and creating underground waste. Although some of these reservoirs are being produced, such production must be considered in the nature of a salvage operation rather than as a sound economic proposition. Such reservoirs, however, can become profitable ventures through the use of cycling and repressuring plants.

Cycling operations now operating in Louisiana have increased the ultimate recovery from gas-condensate reservoirs anywhere from 10 to 30 per cent. Cycling operations will also provide a considerable reserve of gas, without which Louisiana cannot hope to develop any program of industrialization.

During the past year, Louisiana attained the rank of third among the oil-producing states of this country. With a proper program of exploitation and development, and with emphasis on conservation, Louisiana can maintain this position for a great many years.

Production

On Dec. 31, 1943, oil and/or gas were being produced in 52 parishes, or 81 per cent of all the parishes in the state. Thirty-three of the parishes produced oil and gas, 14 produced oil, and 5 produced solely gas.

Tensas Parish in north Louisiana and Assumption Parish in south Louisiana formerly contained no producing fields but during 1943 joined the ranks of the producing parishes.

Twenty-three new fields, including one rediscovery, were found during 1943—a rate of discovery almost comparable to that of the preceding year. Eleven of these new discoveries were either gas or gas-condensate fields. Thus, the trend of development in finding new reserves was also comparable to that of 1942.

Many reasons of considerable merit have been advanced to account for the discouraging lack of crude-oil reserves found during the past year. None are, however, completely satisfactory.

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‡ See G. J. Smith: Review of Developments in 1942, Gulf Coast of Upper Texas and Louisiana, *Bull.* Amer. Assn. Petr. Geol. (1943) **27** (6), 738.

Statewide production for 1943 was approximately 126.5 million barrels of crude oil and condensate. This amounted to about 8.5 per cent of the total production of liquid hydrocarbons in the United States. A comparison of production for the years 1943 and 1942 shows that Louisiana produced approximately 7.4 million additional barrels of crude oil during the past year. In considering the great demand for oil during the past year, this increase in production cannot be considered as very striking.

COMPLETIONS

Completion records from January to December 1943 show that 614 wells were drilled in or adjoining producing fields. These wells were drilled to deepen or extend producing areas and are not considered as wildcat wells. Of this total number, 383 were completed as oil wells and 85 as gas wells, and the remaining 146 were dry holes. This means that 76 per cent of the wells drilled were successful compared with 83 per cent of the wells for 1942. A comparison of the total number of field wells drilled during 1943 with the 757 that were drilled during 1942 indicates a decrease of slightly less than 20 per cent for 1943. The conclusion is therefore apparent that during 1943 there was a decrease in the number of successful completions. The fact that there were fewer successful completions during the past year may well be the result of the arbitrary spacing program brought on through the necessity of attempting to allocate fairly the use of materials for drilling wells. The arbitrary spacing has probably tended to locate wells in less favorable structural positions. This is especially true on piercement-type salt domes and on those complexly faulted nonpiercement-type domes. The general application of 40-acre spacing, especially in the development of the outer or flank areas of producing structures, cannot be generally applied and each location must be based not on arbitrary spacing rules but upon the prevailing geological conditions if maximum completions are expected.

During 1943 conditions of spacing and drilling were very similar to those of 1942. Thus, for the first time we have an actual comparison of conditions. The comparisons show that there is not only a trend toward decreasing the number of field wells drilled but also toward decreasing the number of successful completions. The probable cause of this trend is the complexity of the domal-type structures found in Louisiana, and although the drilling of unnecessary wells is a thing of the past, the drilling of each structure is a separate problem in itself and cannot be governed by arbitrary rule.

GAS PRODUCTION

Production of casinghead gas in 1943 amounted to 184,000,000 M cu. ft. and natural gas to 515,000,000 M cu. ft., or a total gas production of 669,000,000 M cu. ft. These figures indicate that the total gas production for Louisiana during 1943 was approximately the same as the total gas production for 1942. Production of natural gas increased approximately 10 per cent, while production of casinghead gas decreased about 10 per cent. This trend is a very healthy one and should be not only continued but increased.

During 1943 Louisiana continued to add to its considerable gas reserves. As already indicated, 11 of the 23 new fields discovered during the past year were gas-condensate fields.

Louisiana, in comparison with other states, and with the exception of its oil and gas deposits, has no other exceptional mineral deposits. Most of its minerals are those commonly found in other states. Louisiana can utilize its mineral resources, however, because of the enormous advantage of having a huge supply of cheap fuel in the form of natural gas. If Louisiana, for example, is to develop and maintain a ceramic industry, it must conserve its natural gas deposits until a time when this fuel can be utilized intrastate instead of sending natural gas to other states that utilize the gas to fabricate products that in turn are sold in Louisiana. This is a cycle which is not conducive to a good state economy. Further, natural gas is becoming the basis for industries developing fuel, chemicals, and other types of materials that will be needed in the industrial development of this country. Natural gas should be exploited in Louisiana.

New Fields, New Sands, and Extensions

North Louisiana

In north Louisiana interest has been equally divided during the past year, as indicated by wildcat tests, among the Wilcox, Upper Cretaceous, and Lower Cretaceous. Six new fields were found, as follows:

East Nebo, La Salle Parish.—The discovery well in this field was completed in the Wilcox as an oil well at a depth of 3900 ft. This field apparently is another "one-well" field so common in the Wilcox trend in northeast Louisiana. Three dry Wilcox tests have already been drilled on the north, east, and south flanks.

Holly Ridge, Tensas Parish.—The discovery well was completed in the Tuscaloosa formation of Upper Cretaceous age as an oil well at a depth of 8400 ft. This field probably is one of the more important discoveries found in north Louisiana during 1943. Three producing wells have already been completed, and six more are in various stages of drilling within a radius of 2 miles of the discovery well.

Lucky, Bienville Parish.—The discovery well was completed as a lean gas-condensate well in the Pettit zone of the Sligo formation of Lower Cretaceous age. Three wells have been drilled and completed in addition to the discovery well in the area, one approximately one mile southeast, another 4.5 miles southeast, and a third 3 miles northeast. These three wells have been completed as gas-condensate wells at depths similar to those of the discovery well, strongly suggesting that the four wells are producing from a common pool which covers a very large area.

North Cotton Valley, Webster Parish.—The discovery well was completed as a gas-condensate well at 8450 ft. in the Bodcaw sand, Cotton Valley formation of Jurassic age. The producing area is on the northeast flank of the Cotton Valley structure about 2 miles north from the nearest well in the Cotton Valley field. Undoubtedly there is a structural relationship between these two fields, but it is unlikely that the North Cotton Valley field is an extension of the Cotton Valley field proper.

North Lake St. John, Tensas Parish.—The discovery well was completed in the Wilcox as an oil well at 4400 ft. Two dry holes have been drilled, one prior to the discovery well and one subsequently, therefore it seems reasonable to assume that the field will not cover a very large area.

Northwest Ruston, Lincoln Parish.—The discovery well was completed as a gas well in the Hosston formation of Lower Cretaceous age at a depth of 5900 ft. This field may actually be connected with the old Ruston field, which is about 2½ miles to the southeast. However, the Ruston field, which consists of one shut-in gas well, produces from the Pettit zone of the Sligo formation of Lower Cretaceous age.

A total of 252 field wells were drilled in north Louisiana during 1943. Of this number, 131 found oil production, 66 found gas production, and 55 were dry. Some of these wells found new sands; others extended the producing areas.

A brief summary of the more important of these developments is listed below:

Athens, Claiborne Parish.—Production extended ½ mile southwest by the second gas-condensate well completed in field.

Big Island, Rapides Parish.—Field abandoned August 1943.

Calvin, Winn Parish.—Defined by four dry 6000 to 7500-ft. test wells completely surrounding the producing well and located approximately one mile from production.

Carterville, Bossier Parish.—Test well drilled to 6507 ft. in search of Pettit production proved dry.

Catahoula Lake, La Salle Parish.—Extended ¼ mile northwest and southwest; defined in northeast by dry Wilcox test (4223 ft.) ¼ mile from production.

TABLE 1.—*Oil and Gas Production in Louisiana*

Line Number	Field, *Parish*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
	NORTH LOUISIANA									
1	Ajax, *DeSoto and Natchitoches*	1941	120	4,605	0	0	0	2	0	2[11]
2	Athens, *Claiborne*	1940	640+	13,261[3]	10,061[3]	1,082	844	2	1	0
3	Bear Creek, *Bienville*	1937	4,000	109,939[3]	29,808[3]	9,947	3,541	6	0	0
4	Beekman, *Morehouse*	1942	320	1,119	202	62	49	1	0	0
5	Bellevue, *Bossier*	1921	1,420	10,795,240	191,445	2,635	10	448	1	3[5]
6	Benson, *DeSoto*	1928	320	6,494	0	107	0	5	0	0
7	Bethany, *Caddo*[1]	1916	2,580	3,068[4]	45	0[4]	0	14	0	2
8	Big Island, *Rapides*	1942	40	3,828	0	0	0	1	0	1
9	Blue Lake, *Sabine*	1928	340	24,942[6]	3,576	0[6]	0	11	0	0
10	Caddo (includes Hosston, Pine Island and Vivian areas), *Caddo*[1]	1905	65,000	157,829,240[7]	2,398,119	144,895[7]	1,061	4,862	56	102[5]
11	Calvin, *Winn*	1942	320+	3,868[3]	3,658[3]	*x*	*x*	1	0	0
12	Carterville-Sarepta, *Bossier, Webster*	1922	4,250	2,856,428	42,640	42,694	8	201	0	4[5]
13	Caspiana, *Caddo*	1925	400	0	0	193[8]	0	5	0	0
14	Catahoula Lake, *La Salle*	1942	280	156,939	141,637		77	4	2	0
15	Cedar Grove, *Caddo*	1915	3,840	0	0	0[9]	0	18	0	0
16	Clarks, *Caldwell*	1941	160+	0	0	0	0	1	0	0
17	Converse, *Sabine*	1932	5,760	2,507,896	94,074	56	1	199	0	1
18	Cotton Valley, *Webster*	1922 1926 1936 1936	14,000	43,312,296	4,564,428	317,905	65,444	454	0	15
19	Cypress Bayou, *La Salle*	1941	80	112,156	24,658	35	9	2	0	1
20	Dixie, *Caddo*	1929	1,500	40,835[9]	7,873	0[9]	0	56	0	2
21	Driscoll, *Bienville*	1936	1,500	25,466[3]	4,139[3]	15,682	2,068	4	0	0
22	East Nebo, *La Salle*	1943	40	6,447	6,447	7	7	1	1	0
23	Elm Grove, *Bossier, Caddo*	1916	14,920	3,633,241	102,751	194,631	96	249	0	1
24	Elm Ridge, *La Salle*	1942	40+	7,196	2,727	5	2	1	0	0
25	Epps, *East and West Carroll*	1928	1,280	0	0	9,976	1,223	5	0	0
26	Funny Louis Bayou, *La Salle*	1941	160+	0	0	0	0	1	0	0
27	Grand Cane, *De Soto*	1941	80+	1,400	0	0	0	2	0	2[11]
28	Greenwood, *Caddo*	1940	320	0	0	702	702	2	0	0
29	Grogan, *De Soto*	1937	40	28,671	0	0	0	1	0	0

[1] Extends into Texas.
[3] Condensate only.
[4] Included under Waskom prior to 1941.
[5] Nearest known figure.
[6] Included under Zwolle prior to 1941.
[7] Included Dixie and Cedar Grove prior to 1941.
[8] Included under Elm Grove prior to 1940.
[9] Included under Caddo prior to 1941.
[11] Temporarily abandoned.

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
									NORTH LOUISIANA							
1	0	0	0				42		Paluxy, CreL	S	Por	3,209	5	D	Paluxy	3,500
2	0	0	2				61		Hosston, CreL	S	Por	6,166	10	DF	Hosston	6,706
3	0	0	6				59		Pettit, CreL	OL	16	6,605	25	D	Hosston	8,016
									Hosston, CreL	S	12.5	7,215	15	D		
4	0	0	1						Cotton Valley, Jur	S	Por	3,700	20		Eagle Mills salt	6,956
5	0	150	0				18–19		Nacatoch, CreU	S	Por	300	30	DF	Eagle Mills salt	9,070
									Rodessa, CreL	OL	Por	1,700	x	DU		
6	0	0	0						Paluxy, CreL	S	Por	3,000	10	A	Paluxy	3,440
7	0	0	0						Nacatoch, CreU	S	Por	930	25	A	Mooringsport	3,758
									Washita, CreL	S	Por	2,400	10	A		
									Paluxy, CreL	S	Por	2,830	10	A		
8	0	0	0						Wilcox, Eoc	S	Por	5,150	2		Midway	7,105
9	0	1	0				42–45		Chalk Series, CreU	C	Fis	2,100	x	T	Paluxy	4,503
10	0	1,382	17				19–21		Nacatoch, CreU	S	Por	800	30	Af	Igneous below Eagle Mills salt	11,419
							28–39		Saratoga-Annona, CreU	C	Fis	1,400	x	Af		
							23–44		Tokio, CreU	S	Por	2,000	20	Af		
							26–43		Paluxy, CreL	S	Por	2,300[10]	x	Af		
									Ferry Lake, CreL	A	Fis	2,700	x	Af		
									Rodessa, CreL	OL	Por	2,800[10]	x	Af		
							42–44		Sligo, CreL	OL	Por	3,620	x	Af		
									Hosston, CreL	S	Por	3,900	15	Af		
11	0	0	1				72		Paluxy, CreL	S	Por	5,784	10		L. Cretaceous	9,719
12	0	23	0				26–43		Tokio, CreU	S	Por	2,675[10]	30	A	Cotton Valley	10,070
13	0	0	0						Nacatoch, CreU	S	Por	800	20	N	Cotton Valley	9,141
									Eagleford, CreU	S	Por	2,450	8	N		
14	3	1	0				39–43		Wilcox, Eoc	S	Por	4,040[10]	50		Midway	5,400
15	0	0	0						Tokio, CreU	S	Por	2,450	25	A	Hosston	6,001
16	0	0	1						Wilcox, Eoc	S	Por	2,173	12	Df	Wilcox	4,006
17	0	62	1						Saratoga-Annona, CreU	C	Fis	1,600	x	Af	Hosston	8,929
									Paluxy, CreL	S	Por	3,604	20	Af		
18	6	38	110			C	27–30		Ozan, CreU	S, L	27	2,500	30	A	Cotton Valley	9,198
							51–53		Rodessa, CreL	S	24	3,900[10]	35	A		
							49–67		Hosston, CreL	S	17	5,500[10]	10	A		
							41–65		Cotton Valley, Jur	S	17	7,900[10]	40	A		
19	0	1	0				44		Wilcox, Eoc	S	22	4,706	10	AM	Midway	5,976
20	0	4	0				38		Paluxy, CreL	S	Por	2,400	10	T	Mooringsport	3,514
21	0	0	4						Rodessa, CreL	OL	16	5,960	15	D	Hosston	7,693
									Hosston, CreL	S	12	7,160	25	D		
22	1	0	0				37		Wilcox, Eoc	S	Por	3,896	14		Midway	5,208
23	0	39	12				29–30		Nacatoch, CreU	S	Por	800	30	A	Cotton Valley	8,647
									Ozan, CreU	S	Por	1,550	12	A		
									Tokio, CreU	S	Por	1,675[10]	50	A		
									Paluxy, CreL	S	Por	2,400	10	A		
24	0	1	0				41		Wilcox, Eoc	S	Por	4,572	13	AM	Midway	5,976
25	0	0	5						Monroe Gas Rock, CreU	C	Por	2,302	25	D	Eagleford	2,820
26	0	0	1						Sparta, Eoc	S	Por	1,465	10		Wilcox	4,000
27	0	0	0						Paluxy, CreL	S	Por	2,820	10		Paluxy	2,858
28	0	0	2						Paluxy, CreL	S	Por	2,549	20	AM	Paluxy	2,981
29	0	0	0				38–39		Paluxy, CreL	S	Por	2,929	5	D	Paluxy	2,961

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[10] Multiple sand production.

TABLE I.—(*Continued*)

Line Number	Field, *Parish*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
30	Haynesville, *Claiborne, Webster*[2]	1921	12,000	80,388,890	5,341,245	938,434	3,830	918	23	27
31	Holly, *De Soto*	1930	240	1,070,374	35,707	198	30	17	2	0
32	Holly Ridge, *Tensas*	1943	120+	40,228	40,228	30	30	3	3	0
33	Homer, *Claiborne*	1919	3,020	72,998,200	1,057,690	8,189	539	642	1	0
34	Indian Bayou, *La Salle*	1941	40	80,684	45,289	30	16	1	0	0
35	Lake Bistineau, *Bienville*	1916	5,500	32,999[3]	7,938[3]	45,009	11,097	29	1	0
36	Lake End, *Red River*	1942	40	1,307	900	0	0	1	0	0
37	Lake St. John, *Concordia*	1942	800+	389,449	322,437	312	279	19	9	0
38	Larto Lake, *Catahoula*	1941	40	67,362	28,208	0	0	1	0	0
39	Lisbon, *Claiborne, Lincoln*	1936	10,240	10,574,878	586,142	27,967	8,886	275	2	9
40	Logansport, *DeSoto*[1]	1938	14,000	119,478[3]	48,024[3]	30,794	13,002	17	4	0
41	Longwood, *Caddo*	1926	4,560	19,270[3,4]	3,805[3]	8,216[4]	229	38	0	0
42	Lucky, *Bienville*	1943	640+	994[3]	994[3]	282	282	1	1	0
43	Manifest, *Catahoula*	1942	40	2,490	1,893	0	0	1	0	0
44	Monroe, *Ouachita, Morehouse, Union*	1916	251,000	0	0	3,480,467	230,578	1,495	49	5
45	Nebo-Hemphill, *La Salle*	1940	5,920	7,646,821	3,559,731	8,193	3,516	148	9	0
46	North Carterville, *Bossier*	1942	400	85,896	84,869	x[13]	x[13]	6	5	0
47	North Cotton Valley, *Webster*	1943	160+	1,265[3]	1,265[3]			1	1	0
48	Northeast Lisbon, *Claiborne*	1941	960	0	0	0	0	3	1	0
49	North Lake St. John, *Tensas*	1943	40	13,019	13,019	3	3	1	1	0
50	Northwest Ruston, *Lincoln*	1943	160+	0	0	0	0	1	1	0
51	Oakland, *Union*	1928	60	8,470[12]	2,350	0	0	7	0	0
52	Olla, *La Salle*	1940	8,300	13,529,753	3,755.887	21,628	10,525	191	1	3
53	Pleasant Hill, *De Soto, Sabine*	1927	2,000	1,518,482	23,803	489	73	64	0	1[5]
54	Red River –Bull Bayou, *De Soto, Red River.*	1912	40,000	57,405.732	310,688	69,463	932	1,446	5	17
55	Richland, *Richland*	1926	49,280	0	0	460,619	0	313	0	2
56	Rodessa, *Caddo*[1,2]	1930	18,000	79,294,727	3,484,304	502,160	38,561	504	0	32
57	Ruston, *Lincoln*	1937	320+	0	0	0	0	1	0	0
58	Shongaloo, *Webster*	1921	5,750	179,559	2,778	73,000	93	95	1	2
59	Shreveport, *Bossier, Caddo*	1913	8,200	6,276,293	776,993	13,678	3,059	62	2	2
60	Sibley, *Webster*	1936	1,000	36,771[3]	11,474[3]	7,243	1,857	6	0	0
61	Simsboro, *Lincoln*	1935	700	15,248[3]	6,687[3]	11,623	2,305	2	0	0

[2] Extends into Arkansas.
[12] No records prior to 1941.
[13] Included in Cotton Valley.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
30	139	262	0	2,317	1,750		35–36		Tokio, CreU	S	Por	2,725	25	A	Smackover	11,254
							35		Rodessa, CreL	OL	Por	4,250	20	AL		
							38–42		Sligo, CreL	OL	18	5,200	20	AL		
31	0	6	2				37–39		Eagleford, CreU	S	Por	2,538	11	NL	Paluxy	3,373
32	3	0	0	3,923	3,923				Tuscaloosa, CreU	S	26	8,382	40	D	Tuscaloosa	8,463
33	0	321	0			G	35–38		Nacatoch, CreU	S	Por	1,000	50	DF	Eagle Mills salt	6,019
							35–38		Tokio, CreU	S	Por	1,900	50	DF		
							46		Cotton Valley, Jur	S	Por	4,242	74	DF		
34	1	0	0				44		Wilcox, Eoc	S	Por	4,294	10	AM	Midway	5,905
35	0	0	18						Ozan, CreU	S	Por	1,950	25	AF	Cotton Valley	8,532
									Tokio, CreU	S	Por	2,525	25	AF		
									Sligo, CreL	OL	17	5,000	40	AF		
									Cotton Valley, Jur	S	12	8,400	*x*	AF		
36	0	1	0						Nacatoch, CreU	S	Por	1,224	*x*	D	Hosston	7,120
37	15	1	3						Sparta, Eoc	S	Por	2,131	20	D	Rodessa	9,994
							32–44		Wilcox, Eoc	S	Por	3,396[10]	65	D		
							55		Tuscaloosa, CreU	S	Por	9,000	30	D		
38	0	1	0				46		Wilcox, Eoc	S	22	5,108	25		Midway	7,031
39	0	140	8			G	32–33		Sligo, CreL	OL	18	5,100	10	DL	Eagle Mills salt	12,592
							42		Hosston, CreL	S	Por	5,300	7	DL		
									Cotton Valley, Jur	S	13	8,400[10]	30	DF		
							56		Smackover, Jur	L	Por	10,150	100	DF		
40	0	0	17						Rodessa, CreL	OL	18	4,825	50	A	Hosston	6,271
									Sligo, CreL	OL	12	5,980	20	A		
41	0	0	2						Nacatoch, CreU	S	Por	870	40	A	Hosston	6,200
									Paluxy, CreL	S	Por	2,690	20	A		
									Sligo, CreL	OL	Por	5,590	40	A		
									Hosston, CreL	S	Por	6,000	50	A		
42	0	0	1						Sligo, CreL	OL	Por	6,836	30		Hosston	7,804
43	0	1	0				20		Sparta, Eoc	S	Por	1,810	7		Wilcox	4,554
44	0	0	1,361						Monroe Gas Rock, CreU	C	Por	2,145	30	MC	Morehouse	10,475
									Second Sand, CreU	S	Por	2,265	10	MC		
45	68	78	2				19		Cockfield, Eoc	S	Por	1,420	15	AL	Midway	5,301
							39–43		Wilcox, Eoc	S	25	3,340[10]	400	AL		
46	4	2	0				38–39		Sligo, CreL	OL	Por	6,048	42	AL	Hosston	6,382
47	0	0	1				63		Cotton Valley, Jur	S	Por	8,462	30		Cotton Valley	8,648
48	0	0	3						Hosston, CreL	S	Por	5,100[10]	25	NL	Cotton Valley	7,912
									Cotton Valley, Jur	S	Por	7,785	30			
49	0	1	0				40		Wilcox, Eoc	S	Por	4,435	6		Midway	6,599
50	0	0	1						Hosston, CreL	S	Por	5,878	55		Hosston	5,989
51	0	4	0						CreU	S	Por	2,200	10		U. Cretaceous	3,001
52	38	142	8				26–32		Wilcox, Eoc	S	20	2,040[10]	154	AL	Rodessa	8,997
53	0	24	1				40–43		Paluxy, CreL	S	Por	3,100	15	N	Mooringsport	5,063
54	0	91	16						Nacatoch, CreU	S	Por	725	30	AF	Hosston	6,479
									Saratoga-Annona, CreU	C	Por	850	*x*	AF		
									Paluxy, CreL	S	Por	2,450[10]	10	AF		
55	0	0	0						Tokio, CreU	S	Por	2,349	76	A	Cotton Valley	9,986
56	36	245	158	2,700	300		40–70		Rodessa, CreL	S, L, OL	15–25	5,400[10]	125	AF	Eagle Mills salt	11,486
57	0	0	1						Sligo, CreL	OL	Por	5,300	20	A	Hosston	5,822
58	0	1	1				29		Tokio, CreU	S	20	2,600	15	A	Cotton Valley	10,462
							50–65		Cotton Valley, Jur	S	10	8,850[10]	30	A		
59	11	37	0		400				Nacatoch, CreU	S	Por	875	25	A	Cotton Valley	8,690
									Tokio, CreU	S	Por	2,450	10	A		
									Sligo, CreL	OL	18	5,550	15	A		
60	0	0	6				58		Rodessa, CreL	OL	15	5,500	35	A	Cotton Valley	10,383
61	0	0	2						Rodessa, CreL	OL	17	5,280	12	D	Cotton Valley	10,002
									Hosston, CreL	S	12	6,460	25	D		

TABLE 1.—(*Continued*)

Line Number	Field, *Parish*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	1943	
									Completed	Abandoned
62	Sligo, *Bossier*	1922	15,000	4,025,653	616,816	193,478	29,421	180	8	4[5]
63	South Jena, *La Salle*	1941	600	260,649	67,122	99	28	7	0	0
64	Spider, *De Soto*	1914	500	0	0	341	0	5	0	0
65	Spring Ridge, *Sabine*	1931	200	*x*	0	0	0	2	0	0
66	Standard, *La Salle, Caldwell*	1940	1,500	0	0	1,503	821	4	1	0
67	Sugar Creek, *Claiborne*	1930	4,440	1,967,451	474,436	79,714	9,913	44	8	0
68	Summerville, *La Salle*	1940	740	317,346	117,979	610	94	13	0	0
69	Sutherlin, *De Soto*	1920	1,280	0	0	224	0	4	0	0
70	Trout Creek, *La Salle*	1941	250	159,136	38,900	70	22	6	0	0
71	Tullos-Urania-Georgetown, *Grant, La Salle, Winn*	1925	6,600	26,618,045	733,453	5	0	533	1	16[5]
72	Waskom, *Caddo*	1924	1,600	30,944[3,14]	4,556[3]	13,970	537	32	0	0
73	White Sulphur Springs, *La Salle*	1927	350	12,290	0	0	0	12	0	0
74	Willow Lake, *Catahoula*	1941	80	199,942	97,931	20[5]	20	2	0	0
75	Zenoria-Little Creek, *La Salle*	1938	3,000	2,754,575	975,965	4,052	1,127	76	3	2[5]
76	Zwolle, *Sabine*	1928	28,000	14,867,235[15]	180,142	183	3	382	0	8[5]
	SOUTH LOUISIANA									
77	Abbeville, *Vermilion*	1937	955	825,249	81,324	11,606	2,869	12	0	2
78	Arnaudville, *St. Martin*	1943	40	469	469	5	5	1	1	0
79	Anse la Butte, *Lafayette, St. Martin*	1902	200	7,242,731	2,248,479	2,920	1,065	93	6[16]	4
80	Avery Island, *Iberia*	1942	70	202,541	180,023	108	95	7	6	0
81	Bancroft, *Beauregard*	1938	750	3,324,958	213,305	17,468	1,604	43	0	3
82	Barataria, *Jefferson*	1939	270	3,638,165	1,127,161	2,480	863	23	0	0
83	Bastian Bay, *Plaquemines*	1941	120	76,467	16,501[17]	669	90	3	0	0
84	Bateman Lake, *St. Mary*	1937	4,640	1,602,060	343,102	18,891	9,862	14	0	0
85	Bay Baptiste, *Terrebonne*	1938	640	1,320	0	68	0	1	0	0
86	Bay de Chene (Hackberry Bay), *Jefferson, Lafourche*	1941	160	99,818	63,018	1,273	972	2	0	0
87	Bayou Bleu, *Iberville*	1929	500	2,449,028	793,886	588	240	43	2	0
88	Bayou Bouillon, *St. Martin*	1902	40	429,772	8,010	102	0	15	0	0
89	Bayou Choctaw, *Iberville, West Baton Rouge*	1931	120	4,007,753	169,145	623	69	23	1	0
90	Bayou Couba, *St. Charles*	1942	160	69,559	66,697	21	21	4	3	1
91	Bayou des Allemands, *St. Charles, Lafourche*	1937	520	951,038	320,661	2,835	774	18	3	2
92	Bayou des Glaises, *Iberville*	1940	Abandoned	3,679	0	0	0	1	0	0
93	Bayou Mallet, *Acadia*	1936	360	600,222	82,382	1,299	32	8	0	0
94	Bayou Pigeon, *Iberia*	1940	200	729,837	146,160	361	93	5	0	1
95	Bayou Sale, *St. Mary*	1941	1,500	2,998,434	1,912,147	3,516	2,083	34	10	0
96	Bay St. Elaine, *Terrebonne*	1937	180	944,722	121,212	722	137	14	0	0
97	Bear, *Beauregard*	1943	200	113,574	113,574	291	291	6	6[18]	0

[14] Included Bethany and Longwood prior to 1941.
[15] Included Blue Lake prior to 1941.
[16] Five dual completions.
[17] Produced only eight months.
[18] One dual completion.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil: Flowing	Oil: Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
62	3	67	44						Nacatoch, CreU	S	Por	830	40	Df	Hosston	6,122
									Ozan, CreU	S	Por	1,600	15	Df		
									Tokio, CreU	S	Por	2,460	10	Df		
									Paluxy, CreL	S	Por	2,640	15	Df		
							41–43		Mooringsport, CreL	L	Por	3,000	10	Df		
							57		Rodessa, CreL	OL	15	4,150	30	Df		
							49		Sligo, CreL	OL	17	4,925	50	Df		
63	0	6	1				33–43		Wilcox, Eoc	S	26	3,272^{10}	51	NL	Midway	5,062
64	0	0	0						Paluxy, CreL	S	Por	2,800	20	A	Hosston	6,063
65	0	0	0				39		Paluxy, CreL	S	Por	3,350	5	D	Mooringsport	3,723
66	0	0	4						Wilcox, Eoc	S	Por	2,164^{10}	52	Df	U. Cretaceous	5,097
67	15	2	25						Rodessa, CreL	OL	18	4,300	13	AF	Cotton Valley	10,759
							32–37		Sligo, CreL	OL	14	4,900^{10}	50	AF		
							34		Hosston, CreL	S	25	5,550	18	AFL		
68	2	9	1				28–33		Wilcox, Eoc	S	20	2,512^{10}	45	NL	Midway	4,071
69	0	0	0						Paluxy, CreL	S	Por	2,775	10	D	Paluxy	3,003
70	0	6	0				35–43		Wilcox, Eoc	S	28	3,168^{10}	49	NL	Midway	4,810
71	0	199	0				21–22		Wilcox, Eoc	S	Por	1,490	9	Nf	Tokio	6,463
72	0	0	3						Nacatoch, CreU	S	Por	925	30	A	Hosston	6,400
									Tokio, CreU	S	Por	1,875^{10}	50	A		
									Paluxy, CreL	S	Por	2,540	30	A		
									Hosston, CreL	S	13	6,157	15	A		
73	0	0	0				20		Cockfield, Eoc	S	Por	794	9	Nf	Wilcox	2,435
74	2	0	0				37		Wilcox, Eoc	S	Por	5,533	6	NL	Midway	6,810
75	4	60	4				19–38		Wilcox, Eoc	S	28	1,612^{10}	190	A	Midway	4,124
76	0	33	0				42		Annona, CreU	C	Fis	2,100	x	A	Rodessa	6,178
									SOUTH LOUISIANA							
77	1	0	7				50	0.1	MioU	S	26	6,400	141	D	Uvigerina	12,214
78	1	0	0				42		MioL	S	Por	10,340	35	D	L. Miocene	10,700
79	56	10	0				23		Pli	S	Por	1,165	40	Ds	L. Miocene	9,936
							23–40		MioU	S	30	2,800	502	Ds		
							32		MioL	S	25	9,430	28	Ds		
80	7	0	0						MioU	S	Por	8,900	80	Ds	U. Miocene	12,005
81	5	17	1				41		Cockfield, Eoc	S	28	7,250	15	AF	Wilcox	11,018
82	20	0	0				37	0.2	MioU	S	32	7,600	80	D	U. Miocene	12,246
83	0	0	0				40		MioU	S	Por	9,350	28	D	U. Miocene	10,174
84	3	0	5				33–45		MioU	S	25	8,600	286	D	U. Miocene	11,876
85	0	0	0				49		MioU	S	Por	11,200	5	D	U. Miocene	13,409
86	1	0	0						Pli	S	Por	2,500	50	Ds	U. Miocene	9,887
							33		MioU	S	Por	7,470	30	Ds		
87	27	6	0				19–38		MioU	S	Por	1,250	426	Ds	L. Miocene	11,049
88	0	2	0				20		MioU	S	27	3,200	15	Ds	L. Miocene	9,405
									MioL	S	Por	7,480	15	Ds		
89	2	10	0				26		MioU	S	27	2,400	x	Ds	L. Miocene	10,033
							37		MioL	S	38	7,500	80	Ds		
90	3	0	0				35		MioU	S	Por	6,462	20	Ds	U. Miocene	8,440
91	8	2	0				35	0.2	MioU	S	Por	5,425	270	Ds	U. Miocene	10,794
92	0	0	0				38	0.1	MioL	S	Por	8,640	7	Ds	L. Miocene	10,380
93	3	0	2				30		MioL	S	Por	6,380	45	D	Vicksburg	8,404
94	3	0	0				27		MioU	S	30	8,050	20	D	L. Miocene	11,934
95	31	0	0				35–49		MioU	S	30	4,540	400	D	U. Miocene	12,404
96	6	1	0				29		MioU	S	Por	5,600	200	Ds	U. Miocene	12,689
97	5	0	1				42–43		MioL	S	Por	6,104	30		Cook Mt.	9,414

TABLE 1.—(*Continued*)

Line Number	Field, *Parish*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
98	Belle Isle, *St. Mary*	1941	20	5,764	1,604	452	111	1	0	0
99	Big Lake, *Cameron*	1935	40	78,851	6,513	282	19	6	1	0
100	Black Bayou, *Cameron*	1929	340	10,739,993	1,100,337	2,709	809	40	2	0
101	Bosco-Cankton, *Acadia, St. Landry*	1934	2,240	24,429,193	1,094,719	49,616	2,688	72	0	2
102	Branch, *Acadia*	1942	640	75,230	10,418	4,638	866	2	1	0
103	Bully Camp, *Lafourche*	1942	40	0	0	79	67	2	1	0
104	Caillou Island, *Terrebonne*	1930	540	35,553,419	1,833,826	4,369	1,381	58	3	1
105	Cameron Meadows, *Cameron*	1931	300	9,779,734	636,745	1,028	144	69	1	6
106	Chacahoula, *Lafourche*	1938	380	2,907,741	937,194	2,183	654	24	6	1
107	Chalkley, *Cameron*	1938	2,000	5,868,944	1,498,314	12,803	3,230	39	0	1
108	Charenton, *St. Mary*	1936	750	10,909,364	1,116,557	3,684	360	206	1	20
109	Cheneyville, *Rapides*	1935	640	4,490,565	823,569	15,636	2,393	49	0	0
110	China, *Jefferson Davis*	1940	Abandoned	7,110	0	822	0	1	0	0
111	Creole, *Cameron*	1938	160	2,189,689	220,513	1,417	253	10	0	0
112	Darrow, *Ascension*	1932	175	5,936,848	446,814	2,473	154	23	0	0
113	Deer Island, *Terrebonne*	1942	640		0	0	0	2	1	0
114	Delacroix Island, *Plaquemines*	1941	200	158,738	110,316	661	481	5	3	0
115	Delarge, *Terrebonne*	1938	640	294,837	100,737	10,252	3,541	2	1	0
116	Delta Duck Club, *Plaquemines*	1941	80	64,545	3,543	147	0	2	0	0
117	Delta Farms, *Jefferson, Lafourche*	1940	900	1,517,067	1,018,774	2,222	1,120	20	9	0
118	Dog Lake, *Terrebonne*	1935	160	3,144,418	441,268	1,817	726	17	0	1
119	East Gibson, *Terrebonne*	1943	40	7,746	7,746	6	6	1	1	0
120	East Hackberry, *Cameron*	1927	900	31,706,235	1,826,273	6,464	1,267	155	3	12[5]
121	East White Lake, *Vermilion*	1940	400	860,502	562,052	1,691	530	17	7	1
122	Edgerly, *Calcasieu*	1912	215	8,565,011	56,848	2	0	177	0	1
123	Egan, *Acadia*	1943	320	6,687	6,687	254	254	2	2	0
124	Eola, *Avoyelles*	1939	2,100	15,045,686	3,133,307	21,966	4,824	102	1	1
125	Erath, *Vermilion*	1940	2,400	500,839	228,305	3,685	1,717	43[19]	32	0
126	Fausse Point, *Iberia, St. Martin*	1926	160	341,375	171,784	1,400	482	20	3	0
127	Fields, *Beauregard*	1943	160	1,256	1,256	43	43	1	1	0
128	Four Island Bay, *Terrebonne*	1935	Abandoned	102,512	0	0	0	2	0	0
129	Freshwater Bayou, *Vermilion*	1942	320	0	0	0	0	1	0	0
130	Garden Island Bay, *Plaquemines*	1935	420	7,339,485	1,355,574	2,326	840	47	4	0
131	Gibson, *Terrebonne*	1937	480	7,965,257	1,700,429	14,062	8,036	27	5	0
132	Gillis-English Bayou, *Calcasieu*	1934	1,200	22,541,820	489,866	34,396	2,923	120	0	25[5]
133	Golden Meadow, *Lafourche*	1938	1,400	17,698,470	3,599,467	8,677	2,320	217	1	10
134	Grand Bay, *Plaquemines*	1938	1,200	8,308,029	2,510,732	7,667	2,713	42	3	0
135	Grand Lake, *Cameron*	1939	600	5,330,216	953,971	4,343	1,007	24	0	0
136	Gueydan, *Vermilion*	1932	280	3,880,124	1,247,563	3,266	1,144	32	4	2
137	Hayes, *Calcasieu*	1942	640	10,581	3,420	701	210	2	1	0
138	Happytown, *St. Martin*	1939	80	567,639	139,194	899	353	2	0	0
139	Hester (Vacherie), *St. James*	1938	150	126,582	23,250	899	255	5	3	1
140	Hope Villa, *East Baton Rouge*	1943	40	14,851	14,851	6	6	1	1	0
141	Horseshoe Bayou, *St. Mary*	1937	560	2,220,155	454,879	3,174	1,552	11	1	0
142	Iberia, *Iberia*	1917	300	29,586,218	2,610,258	5,360	902	122	0	13
143	Iowa, *Calcasieu, Jefferson Davis*	1931	1,040	51,674,546	2,929,006	37,623	4,157	99	0	7[5]
144	Jeanerette, *St. Mary*	1935	300	10,957,439	616,615	3,335	656	28	0	1
145	Jefferson Island, *Iberia*	1938	160	1,415,049	278,673	1,327	152	14	2	2

[19] Includes gas input wells.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
98	0	0	1				47		MioU	S	Por	9,800	55	Ds	U. Miocene	12,012
99	1	0	0				39		MioU	S	Por	8,571	15		L. Miocene	13,086
100	13	9	0				22–30	0.15	MioU	S	35	4,200	1,200	Ds	L. Miocene	8,480
							37–45		MioL	S	35	7,500	360	Ds		
101	26	9	0			PM	38–48		MioL	S, LS	Por	7,900	180	D	Vicksburg	10,434
102	6	0	1						MioL	S	Por	9,900	40	D	Vicksburg	10,557
103	0	0	1						MioU	S	Por	996	20	Ds	U. Miocene	8,425
104	39	12	0				35		MioU	S	Por	3,700	1,020	Ds	U. Miocene	11,289
105	9	20	0				20		Pli	S	Por	1,300	30	Ds	Salt	9,331
							28–42		MioU	S	Por	3,300	150	Ds		
106	19	0	1				34		MioU	S	Por	4,235	230	Ds	U. Miocene	10,233
107	28	0	0				36		MioU	S	Por	7,100	160	D	L. Miocene	11,693
							37		MioL	S	Por	8,400	60	D		
108	11	124	0				22		MioU	S	Por	950	185	D	U. Miocene	10,690
109	15	11	3				44		Cockfield, Eoc	S	Por	5,350	90	Ds	Wilcox	8,230
							44		Sparta, Eoc	S	Por	6,150	10	Ds		
110	0	0	0				47		MioL	S	Por	9,300	20	D	L. Miocene	9,965
111	8	0	0				34		MioU	S	Por	5,200		D	L. Miocene	9,895
112	15	1	0				30	0.12	MioU	S	25	4,250	268	Ds	L. Miocene	10,013
							39		MioL	S	25	8,260	27	Ds		
113	0	0	0						MioU	S	Por	9,565	70	D	U. Miocene	11,470
114	5	0	0				36		MioU	S	Por	8,915	90	D	U. Miocene	11,165
115	1	0	1				51		MioU	S	Por	13,000	65	D	U. Miocene	13,563
116	1	0	0				42		MioU	S	25	10,750	45	D	U. Miocene	11,494
117	19	0	0				35		MioU	S	Por	8,800	140	D	U. Miocene	12,015
118	9	1	1				33–52		MioU	S	Por	6,700	90	Ds	U. Miocene	11,648
119	1	0	0				33		MioU	S	Por	9,280	10	D	U. Miocene	10,600
120	24	20	1				27		MioU	S	33	2,700	350	Ds	L. Miocene	11,667
							33		MioL	S	Por	6,150	150	Ds		
121	14	0	1				35		MioU	S	Por	5,900	180	D	U. Miocene	11,163
122	0	13	0				22		MioU	S	Por	3,074	18	Ds	Vicksburg	9,816
123	0	0	1				50		MioL	S	Por	10,480	35	D	Vicksburg	11,199
124	65	21	1				36		Cockfield, Eoc	S	Por	6,400	20	D	Wilcox	11,955
							48		Sparta, Eoc	S	Por	7,600	20	D		
							42		Wilcox, Eoc	S	22	8,500	100	D		
125	0	0	7						MioU	S	29	8,700	995	D	U. Miocene	12,005
126	6	0	1				35		MioU	S	Por	6,640	45	Ds	L. Miocene	12,125
127	0	0	1				74		Cockfield, Eoc	S	Por	8,011	18		Cane River	10,512
128	0	0	0				44		MioU	S	Por	5,500	35	Ds	U. Miocene	10,725
129	0	0	0						MioU	S	Por	11,200	15	D	U. Miocene	11,895
130	32	4	0				35		MioU	S	28	4,100	400	Ds	U. Miocene	7,713
131	22	1	3				37		MioU	S	32	8,600	230	D	U. Miocene	11,440
132	3	20	6				31		MioU	S	Por	5,220	90	D	Vicksburg	9,240
							36		MioL	S	Por	6,400	120	D		
133	71	69	0				36		MioU	S	33	2,600	392	D	U. Miocene	12,526
134	39	0	0						MioU	S	Por	6,149	250	D	U. Miocene	12,034
135	22	0	0				32		MioU	S	Por	8,200	125	D	L. Miocene	11,386
136	17	4	2				30		MioU	S	Por	4,000	120	Ds	L. Miocene	11,163
							32–60		MioL	S	Por	9,200	250	Ds		
137	0	0	0				44		MioL	S	Por	11,620	50	D	L. Miocene	11,960
138	2	0	0				41	0.12	MioL	S	Por	9,750	35	D	L. Miocene	10,900
139	2	0	2				39		MioU	S	Por	5,342	20	Ds	Salt	10,774
							48		MioL	S	Por	9,340	80	Ds		
140	1	0	0				45		MioL	S	Por	9,570	10	D	L. Miocene	9,874
141	7	0	1				38–46		MioU	S	Por	10,180	180	D	U. Miocene	12,777
142	47	27	0				18		Pli	S	Por	800	50	Ds	U. Miocene	11,408
							24		MioU	S	33	2,800	1,105	Ds		
143	48	12	2				30		MioU	S	Por	3,800	400	D	Vicksburg	9,287
							36–58		MioL	S	30	7,050	350	D		
144	11	6	0				35		MioU	S	28	6,400	200	Ds	U. Miocene	11,634
145	5	5	0				33		MioU	S	30	3,070	220	Ds	U. Miocene	10,395

TABLE I.—(*Continued*)

Line Number	Field, *Parish*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	1943	
									Completed	Abandoned
146	Jennings, *Acadia*	1901	800	84,108,159	3,437,154	22,188	2,628	705	1	5
147	Kenilworth, *St. Bernard*	1939	320	125,526	6,027	526	0	2	0	0
148	Krotz Springs, *St. Landry*	1942	360	14,158	13,938	286	286	1	0	0
149	Lafitte, *Jefferson*	1935	2,600	35,691,461	4,684,959	36,163	4,645	64	0	0
150	Lafourche Crossing, *Lafourche*	1939	160	1,149,631	151,140	6,663	4,886	7[20]	0	1
151	Lake Arthur, *Jefferson Davis*	1937	1,600	1,221,628	117,544	23,199	4,333	12	0	2[5]
152	Lake Barre, *Terrebonne*	1929	500	17,829,181	160,543	857	76	40	0	0
153	Lake Chicot, *St. Martin*	1941	240	919,069	557,408	721	404	11	4	1
154	Lake De Cade, *Terrebonne*	1942	120	41,720	27,130	107	102	2	1	0
155	Lake Hermitage, *Plaquemines*	1934	100	156.417	1,343	81.3	0.3	4	0	0
156	Lake Long, *Lafourche*	1937	1,000	3,252,622	825,823	46,587	19,593	18	1	0
157	Lake Mongoulois, *St. Martin*	1939	40	141,821	40,749	6,195	2,112	3	0	0
158	Lake Pelto, *Terrebonne*	1929	200	2,884,993	401,296	1,066	260	23	2	0
159	Lake Salvador, *St. Charles*	1940	720	2,367,070	989,622	2,197	1,090	19	2	0
160	Lakeside (Lowry), *Cameron*	1941	320	29,958	47[21]	1,679	2	4	0	0
161	Lake Washington, *Plaquemines*	1931	200	3,350,704	146,498	*x*	*x*	7	0	0
162	Lapeyrouse, *Terrebonne*	1941	160		0	17	0	1	0	0
163	La Pice, *St. James*	1939	160	490,235	175,339	9,235	2,158	6	2	0
164	La Place, *St. John the Baptist*	1938	320	221,058	75,246	11,931	4,199	3	0	0
165	Leeville, *Lafourche*	1931	900	25,397,077	1,254,411	4,941	821	137	5	3
166	Lewisburg, *Acadia, St. Landry*	1941	960	63,586	33,857	1,511	938	3	0	0
167	Lirette, *Terrebonne*	1937	1,320	453,193	208,371	44,367	15,870	9	1	0
168	Little Cheniere, *Cameron*	1940	80	10,079	0[22]	211	0	2	0	0
169	Lockport, *Calcasieu*	1924	640	15,277,149	257,472	3,096	278	78	0	2[5]
170	Napoleonville, *Assumption*	1943	40	26,577	26,577	17	17	1	0	0
171	Neale, *Beauregard*	1940	3,170	3,404,130	1,343,620	3,334	1,906	34	10[23]	0
172	Nibletts, *Jefferson Davis*	1940	Abandoned	5,390	0[24]	4	0	1	0	0
173	North Crowley, *Acadia*	1937	630	8,330,324	1,704,510	17,699	4,946	45	1	0
174	Northeast Gibson, *Terrebonne*	1941	500	1,140,876	840,734	851	637	14	8	0
175	North Elton, *Allen*	1939	240	59,646	24,248	2,905	1,113	3	0	0
176	North Jeanerette, *St. Mary*	1943	40	38,869	38,869	178	178	1	1	0
177	North Richie, *Acadia*	1943	80	17,392	17,392	94	94	2	0	0
178	North Tepetate, *Acadia*	1938	1,600	150,645	17,591	5,148	631	7	0	0
179	Paradis, *St. Charles*	1939	5,760	7,671,240	4,172,340	6,970	3,735	64	13	0
180	Pecan Island, *Vermilion*	1943	1,800	1,329	1,329[25]	200	200	3	0	0
181	Pecan Lake, *Cameron*	1941	640	7,745	29[26]	201	2	2	0	0
182	Perkins, *Calcasieu*	1939	100	5,104	5,104	207	61	2	2	0
183	Pine Prairie, *Evangeline*	1912	720	2,552,238	1,423,503	2,190	1,455	49	15[27]	0
184	Plumb Bob, *St. Martin*	1939	160	422,816	74,337	157	86	4	0	0
185	Point au Fer, *Terrebonne*	1941	640	336	0[28]	99	0	2	0	0
186	Port Allen, *W. Baton Rouge*	1941	240	420,578	156,759	800	218	6	0	0
187	Port Barre, *St. Landry*	1929	500	12,031,553	1,231,063	1,638	690	85	4	3

[20] One dual completion.
[21] Only produced in June—Four gas wells shut in.
[22] No production in 1943.
[23] Two dual completions.
[24] No production in 1943.
[25] Off production in Nov. & Dec.
[26] Produced only in June—two gas wells shut in.
[27] One dual completion.
[28] No production in 1943.

TABLE I.—(*Continued*)

	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.			Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
Line Number	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943	Secondary Recovery[h]	Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
146	41	64	1				25		MioU	S	Por	1,000	33	Ds	Vicksburg	10,766
							38		MioL	S	28	5,400	500	Ds		
147	1	0	0				34		MioU	S	Por	10,350	40	Ds	U. Miocene	11,469
148	0	0	0				50		MioL	S	Por	9,260	70	D	Eocene	11,403
149	52	6	0				37		MioU	S	29	4,400	320	D	U. Miocene	12,115
150	0	0	5				40		MioU	S	31	9,345	15	D	U. Miocene	11,000
151	1	0	5				53		MioU	S	30	8,500	50	D	L. Miocene	12,088
							54		MioL	S	28	9,500	35	D		
152	5	17	0				30		MioU	S	Por	3,645	50	Ds	Salt	11,333
153	10	0	0				40–60		MioU	S	Por	7,200	120	D	L. Miocene	11,980
154	1	0	0				35		MioU	S	Por	10,200	30		U. Miocene	13,417
155	0	3	0				31	0.06	MioU	S	Por	3,190	69	Ds	U. Miocene	9,786
156	11	0	7				36–51		MioU	S	Por	9,070	210	D	U. Miocene	11,347
157	0	0	2				48		MioL	S	33	9,775	60	Ds	L. Miocene	10,778
158	13	3	0				43		Pli	S	Por	1,350	25	Ds	U. Miocene	11,478
							34		MioU	S	Por	5,200	290	Ds		
159	19	0	0				34		MioU	S	Por	9,600	136	D	U. Miocene	11,063
160	0	0	0				50		MioL	S	Por	9,820	150	D	L. Miocene	11,059
161	7	0	0				18	0.73	Cap Rock	L	Cav	1,150		Ds	U. Miocene	6,445
162	0	0	0				37		MioU	S	Por	10,900	6	D	U. Miocene	10,942
163	4	0	2				39		MioU	S	31	7,800	50	D	L. Miocene	11,851
							37–53		MioL	S	Por	10,132	75	D		
164	0	0	3				54		MioU	S	32	8,100	40	D	L. Miocene	11,005
165	9	51	1						MioU	S	Por	2,930	986	Ds	L. Miocene	11,065
166	2	0	1				53		MioL	S	30	9,090	40	Ds	Oligocene?	10,782
167	0	0	7				51	0.34	MioU	S	Por	8,450	100	D	U. Miocene	12,165
168	0	0	0				47		MioU	S	28	10,185	10	D	U. Miocene	10,655
169	7	13	0				23		Pli	S	Por	1,000		Ds	Salt	8,187
							32		MioU	S	Por	5,300		Ds		
			0				41		MioL	S	Por	6,400	40	Ds		
170	1	0					37		MioU	S	Por	9,030	10	Ds	U. Miocene	11,128
171	23	5	0				37–46		Wilcox, Eoc	S	22	8,300	150	Ds	Cretaceous?	12,584
172	0	0	0				42		MioL	S	Por	11,600	16	Ds	L. Miocene	11,748
173	31	6	1				38	0.17	MioU	S	Por	7,180	26	Ds	L. Miocene	10,652
							36		MioL	S	Por	7,744	100	D		
174	14	0	0				37		MioU	S	32	8,370	220	D	U. Miocene	10,535
175	0	0	2				53		MioL	S	Por	7,400	15	D	Vicksburg	9,010
176	1	0	0				34		MioU	S	Por	11,457	10	D	U. Miocene	12,261
177	2	0	0				37		MioL	S	Por	8,580	25	D	L. Miocene	9,909
178	0	0	4				44–55		MioL	S	30	7,900	90	D	Marginulina	9,487
179	57	0	0				37		MioU	S	25	9,550	300	D	U. Miocene	11,555
180	0	0	0				37–50		MioU	S	Por	7,500	160	D	U. Miocene	12,057
181	0	0	0				46		MioU	S	Por	10,140	45	D	L. Miocene	10,140
182	0	0	0				25		MioL	S	Por	5,367	15	D	Cockfield	9,450
183	42	0	0				40		Cockfield, Eoc	S	Por	7,530	40	Ds	Wilcox	10,850
							40–47		Sparta, Eoc	S	Por	7,875	80	Ds		
									Wilcox, Eoc	S	Por	10,062	250	Ds		
184	2	1	0				34		MioL	S	24	8,300	60	Ds	L. Miocene	9,771
185	0	0	0				57		MioU	S	Por	5,608	30	D	U. Miocene	11,732
186	3	1	0						MioL	S	30	9,100	60	D	L. Miocene	10,044
187	22	25	1						MioU	S	Por	1,300		Ds	L. Miocene	8,376
							21–60		MioL	S	32	3,100	430	Ds		
							26		Olig	S	Por	3,600	20	Ds		
							36		Claiborne, Eoc	S	Por	5,116	20	Ds		

TABLE 1.—(*Continued*)

Line Number	Field, *Parish*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
188	Potash, *Plaquemines*	1937	200	2,341,085	694,574	1,372	626	20	3	0
189	Quarentine Bay, *Plaquemines*	1937	1,700	9,706,253	2,556,460	8,997	3,022	46	2	1
190	Rabbit Island, *Iberia*	1942	320	691	691[29]	56	56	1	0	0
191	Raceland, *Lafourche*	1938	520	3,145,672	771,314	8,244	1,586	16	1	0
192	Reddell, *Evangeline*	1943	80	7,196	7,196	76	76	2	2	0
193	Richie, *Acadia*	1941	320	635,454	227,085	8	0?	14	0	0
194	Roanoke, *Jefferson Davis*	1934	1,080	10,355,826	602,282	23,873	2,649	35	3	1
195	Rosedale, *Iberville*	1943	40	5,738	5,738	2	2	1	1	0
196	St. Gabriel, *Iberville*	1941	1,290	3,616,397	1,733,007	1,582	940	27	2	0
197	St. James, *St. James*	1943	120	4,561	4,561	161	161	1	1	0
198	St. Martinville, *St. Martin*	1935	80	1,351,805	57,057	425	18	2	0	0
199	Section 28, *St. Martin*	1940	120	47,965	12,432	194	3	2	0	0
200	Shuteston, *St. Landry*	1943	40	15,118	15,118	60	60	1	1	0
201	Sorrento, *Ascension*	1928	100	1,224,320	33,076	42	2	12	0	0
202	South Crowley, *Acadia*	1938	200	129,360	12,365	132	28	6	0	1
203	South Elton, *Jefferson Davis*	1937	640	68,536	3,467[30]	1,871	76	1	0	0
204	South Houma, *Terrebonne*	1938	80	641,055	67,185	2,875	473	2	0	0
205	South Jennings, *Jefferson Davis*	1936	1,500	217,981	76,681	35,507	17,062	8	0	1[5]
206	South Lewisburg, *Acadia*	1943	40	1,369	1,369	17	17	1	1	0
207	South Thornwell, *Jefferson Davis*	1942	320	1,759	1,221[31]	113	78	1	0	0
208	Starks, *Calcasieu*	1925	150	3,675,272	196,247	34	4	41	0	2[5]
209	Stella, *Plaquemines*	1940	500	644,012	236,917	638	118	8	0	2
210	Sulphur Mines, *Calcasieu*	1926	200	17,466,115	746,237	1,539	213	132	0	3[5]
211	Sweet Lake, *Cameron*	1926	200	6,780,573	648,445	1,118	87	23	0	0
212	Tepetate, *Acadia*	1935	1,000	12,326,420	896,690	65,565	7,227	60	1	0
213	Timbalier Bay, *Lafourche*	1938	80	267,126	25,653	33	9	2	0	0
214	University, *E. Baton Rouge*	1938	940	14,889,602	2,897,368	22,526	5,678	101	2	2
215	Unknown Pass, *Orleans*	1941	Abandoned	9,031	76[32]	52	2	2	0	2
216	Valentine, *Lafourche*	1936	220	5,562,364	148,682	2,163	93	35	0	1
217	Venice, *Plaquemines*	1937	520	6,634,914	2,130,507	5,787	1,942	33	3	1
218	Vermilion Bay, *Iberia*	1939	80	501,151	109,457	745	239	4	1	0
219	Ville Platte, *Evangeline*	1937	5,200	25,665,525	4,451,446	163,370	39,508	234[33]	7	1
220	Vinton, *Calcasieu*	1910	680	44,185,493	664,652	198	172	467	16	15[5]
221	Welsh, *Jefferson Davis*	1902	200	708,183	15,856	275	11	171[5]	1	1
222	West Bay, *Plaquemines*	1940	680	2,052,861	885,467	2,300	967	19	2	1
223	West Cote Blanche Bay, *St. Mary*	1940	680	1,586,885	663,934	1,357	661	18	3	1
224	West Gueydan, *Vermilion*	1938	300	959,486	262,058	1,072	634	11	3	1
225	West Hackberry, *Cameron*	1927	680	11,726,449	1,957,462	5,225	1,047	95	10[34]	5[5]
226	West Lake Verrett, *St. Martin*	1938	880	2,675,888	843,696	6,819	2,181	31	3	0
227	West Mermentau, *Jefferson Davis*	1940	400	59,040	25,602	2,216	984	3	1	0
228	Westwego, *Jefferson*	1941	120	256,545	117,331	1,329	467	4	0	0
229	West White Lake, *Vermilion*	1943	160			0	0	1	1	0
230	White Castle, *Iberville*	1929	580	7,374,752	1,279,161	3,653	939	28	1	0
231	Woodlawn, *Jefferson Davis*	1938	1,100	4,523,176	947,431	26,860	6,102	32	0	0

[29] Produced only in January and February.
[30] Produced only last three months of 1943.
[31] Produced only in June, July, August, September.
[32] Abandoned in January, 1943.
[33] Ten dual completions.
[34] Three new wells dual completed and four old wells dual completed.

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
188	13	3	0				28	0.1	MioU	S	Por	688	160	Ds	U. Miocene	10,027
189	39	1	0				34		MioU	S	Por	7,690	220	D	U. Miocene	10,536
190	0	0	0						MioU	S	Por	8,670	30	D	U. Miocene	9,930
191	13	0	2				36		MioU	S	Por	7,200	90	D	U. Miocene	12,196
192	2	0	0				57-58		Sparta, Eoc	S	Por	9,905	40	DF	Wilcox	12,200
193	4	8	0				25		MioU	S	Por	3,500	15	D	L. Miocene	9,111
194	8	8	2				33–57		MioL	S	26	6,260	360	D	Vicksburg	10,750
195	1	0	0				34		MioL	S	Por	10,009	10	D	L. Miocene	10,533
196	26	1	0				33		MioL	S	28	7,700	250	D	L. Miocene	10,542
197	0	0	1				51		MioL	S	Por	10,700	30	D	L. Miocene	11,068
198	2	0	0				31		MioU	S	Por	5,500	50	D	L. Miocene	9,645
199	1	0	0				27–47		MioL	S	Por	10,200	50	D	L. Miocene	11,303
200	1	0	0				38		MioL	S	Por	9,495	15	D	Eocene?	11,505
201	4	2	0				23		Pli	S	Por	900	40	Ds	L. Miocene	8,004
							24		MioL	S	Por	4,300	20	Ds		
202	1	0	0				29–53	0.1	MioU	S	25	4,364	70	D	Marginulina	10,272
									MioL	S	Por	8,900	17	D		
203	0	0	1				50		MioL	S	30	8,950	30	D	Claiborne	13,210
204	2	0	0				37	0.1	MioU	S	31	9,750	140	D	U. Miocene	11,344
205	0	0	5				50		MioU	S	31	8,600	45	D	Marginulina	10,953
							50		MioL	S	31	8,800	30	D		
206	0	1	0				60		MioL	S	27	10,306	50	D	L. Miocene	10,504
207	0	0	1				53		MioL	S	Por	9,625	17	D	L. Miocene	10,325
208	3	22	0				18		Pli	S	Por	570	20	Ds	L. Miocene	11,344
							18		MioU	S	Por	740	60	Ds		
							20–40		MioL	S	Por	3,986	110	Ds		
209	6	0	0				40	0 12	MioU	S	32	7,000	60	D	U. Miocene	10,807
210	10	54	0				27		MioU	S	Por	2,760	20	Ds	L. Miocene	7,563
							17–40		MioL	S	Por	4,100	180	Ds		
211	17	0	0				30		MioU	S	Por	5,600	350	D	L. Miocene	9,179
212	30	12	1			Pm	41		MioL	S	25	8,300	120	D	L. Miocene	10,598
213	1	1	0				27		MioU	S	Por	5,330	30	Ds	Salt	8,727
214	38	22	3				36		MioU	S	35	3,900	100	D	L. Miocene	10,362
							43		MioL	S	Por	9,300	150	D		
215	0	0	0				52		MioL	S	Por	9,890	10	D	L. Miocene	10,405
216	6	12	0				33		MioU	S	Por	3,800	350	Ds	L. Miocene	10,357
217	28	0	0				41		MioU	S	30	3,600	800	Ds	U. Miocene	11,402
218	2	0	0				33		MioU	S	29	9,300	110	Ds	U. Miocene	11,603
219	152	34	20				40–60		Sparta, Eoc	S	21	8,700	60	D	Wilcox	12,527
							36–46		Wilcox, Eoc	S	21	9,600	140	D		
220	18	55	0				22		MioU	S	Por	1,850	135	Ds	Salt	6,939
							31 40		MioL	S	Por	4,700	690	Ds		
221	0	11	0				22		Pli	S	Por	1,200	15	Ds	Hackberry	10,358
							37-49		MioL	S	Por	6,120	110	Ds		
222	16	0	0				34		MioU	S	Por	6,260	100	Ds	U. Miocene	10,795
223	13	3	1				21 34		MioU	S	Por	2,000	270	Ds	U. Miocene	10,188
224	6	4	0				39–62		MioU	S	Por	6,600	50	D	L. Miocene	11,000
							37–40		MioL	S	Por	10,000	110	D		
225	39	32	1				21		MioU	S	25	3,050	39	Ds	L. Miocene	10,010
							31		MioL	S	30	4,150	400	Ds		
226	14	8	1				24–37		MioU	S	28	1,300	369	D	U. Miocene	11,890
227	0	0	3				47-57		MioL	S	Por	9,100	20	D	L. Miocene	10,581
228	4	0	0				36		MioU	S	30	9,000	10	D	U. Miocene	11,151
229	0	0	1											D	U. Miocene	12,000
230	10	10	0				28		MioU	S	32	5,150	196	Ds	L. Miocene	10,285
							29		MioL	S	Por	9,320	30	Ds		
231	16	1	6				34–51		MioL	S	30	7,480	250	D	L. Miocene	10,194

Cypress Bayou, La Salle Parish.—One new Wilcox sand discovered; producing area defined on southwest by dry Wilcox test ½ mile southwest of production.

Driscoll, Bienville Parish.—Production defined by a 7000-ft. dry test drilled on the south flank approximately ½ mile south of the producing area.

Elm Ridge, La Salle Parish.—Producing area defined on north by dry Wilcox test (4820 ft.) ¼ mile from production. Production confined to one well; one dry hole previously drilled on southwest.

Haynesville, Claiborne Parish.—Of 25 wells drilled in Louisiana, 23 were completed in the Pettit zone as oil wells and two were abandoned as dry. Pettit production gradually extended ½ mile north in Arkansas; Louisiana producing area defined by 5500-ft. noncommercial well (lack of porosity and permeability) offsetting production on the northeast (sec. 1, T. 23 N., R. 8 W.), and by 5494-ft. dry well on the southwest (sec. 17, R. 23 N., R. 8 W.).

Homer, Claiborne Parish.—Deep test drilled within the old shallow producing area completed in the Cotton Valley at 4300 ft. as a high-ratio oil well. This well tested several other sands in the Cotton Valley formation; Eagle Mills salt was encountered at 5985 feet.

Lake Bistineau, Bienville Parish.—Gas production extended 1¾ miles northwestward on west flank of structure.

Lake St. John, Concordia Parish.—Field extended ¼ mile northwest, east, and southeast. First well completed in the Tuscaloosa formation (previously tested 1942) during 1943.

Lisbon, Claiborne Parish.—Gas-condensate production in the Cotton Valley formation extended one mile southeast. New Cotton Valley sand found productive of gas on upthrown side (north side) of east-west major fault. This new sand extends the Cotton Valley producing area 2 miles northeast, suggesting that the Lisbon field may connect with the northeast Lisbon field now only 2 miles east of Lisbon production.

Logansport, De Soto Parish.—Producing area extended one mile northeast.

Manifest, Catahoula Parish.—Production defined by three 1800-ft. test wells offsetting the producing well on the east and west; now defined on all sides except south. The field produces from only one well.

Nebo-Hemphill, La Salle Parish.—Several locations within producing area drilled for production; second Cockfield sand pumper (10 bbl.) completed about ½ mile northeast of the first (southwest flank of structure); field defined by dry Wilcox tests on northwest, northeast, east, and southeast flanks.

North Carterville, Bossier Parish.—Extended from ¼ to ½ mile in all directions from discovery well.

Red River-Bull Bayou, Red River and De Soto Parishes.—Deep test (5196 ft.) drilled on Coushatta anticline (lobe on east flank of Red River-Bull Bayou structure) about 2½ miles east of old shallow producing area, plugged back and completed as a small gas well at 1050 ft. (Nacatoch sand); this production probably is separated from production at Red River-Bull Bayou, but is characteristic of the small gas pockets associated with the Nacatoch sand over the Sabine uplift; as such it is of minor importance.

Shongaloo, Webster Parish.—Deep test (6032 ft.) drilled to Pettit lime abandoned as dry. A show was tested in the Pettit; attempts to acidize the formation were not successful. The well also tested the Rodessa formation.

Sugar Creek, Claiborne Parish.—Oil-producing area (Hosston formation) extended ½ mile southeast. Production defined on north flank of dome by two 6000-ft. dry holes ¼ mile north of producing area.

Summerville, La Salle Parish.—Production defined by 3175-ft. Wilcox test well on southeast flank of structure, ¼ mile southeast of production.

Willow Lake, Catahoula Parish.—Dry Wilcox test (5870 ft.) drilled ½ mile northeast of producing area. Production now defined on all sides except west.

Zenoria-Little Creek, La Salle Parish.—Production more completely defined by three dry Wilcox test wells (2500 to 3000 ft.) on southwest flank of structure, all of which are approximately ¼ mile from production.

South Louisiana

Seventeen new fields were found in south Louisiana during 1943; eight oil fields and six gas fields. Data available concerning these fields are as follows:

Arnaudville, St. Martin Parish.—The discovery well found gas condensate in a sand at 10,350 ft. This field is an old prospect on which a number of wells have been drilled and abandoned above the depth of the presently producing sand.

Bear, Beauregard Parish.—The discovery well found oil in the Lower Miocene at 6500 ft. Subsequently, a second sand containing gas was found at 6100 ft. The field has now been extended ¼ mile in all directions from the discovery well and defined on the northeast and southwest flanks by dry holes.

Big Lake, Cameron Parish.—This field was discovered in 1935. A gas well and four oil wells were completed. The field was abandoned in 1939. During the past year, the rediscovery well, approximately 500 ft. south of the abandoned producing wells, found oil at 8570 ft. This well was completed at a depth comparable to that of the former producing sand.

Church Point, Acadia Parish.—The discovery well found gas-condensate at 10,300 ft. in the Tweedel sand, which is also productive of gas-condensate in the Lewisburg field 1½ miles to the north.

East Gibson, Terrebonne Parish.—The discovery well found oil at 9280 ft., about one mile east of the Northeast Gibson field. No structural relationship has been established between these two fields, but apparently they are both related to the Gibson field proper.

Egan, Acadia Parish.—The discovery well found gas-condensate at 10,600 ft. Production was subsequently extended ½ mile to the northeast by a second well. This field is an old prospect.

Fields, Beauregard Parish.—The discovery well found gas-condensate production in the Cockfield formation at 8000 ft. Subsequently, a dry Cockfield test was drilled ¼ mile southwest of the discovery well. The field is an old geophysical prospect, first drilled in 1934.

Hope Villa, East Baton Rouge Parish.—The discovery well found oil at 9568 ft. The completion in this area extends the Miocene trend into the Florida Parishes and should stimulate considerable interest in the general area.

Napoleonville, Assumption Parish.—The discovery well found oil at 9000 ft. on the east flank of the dome. The dome was discovered in 1926, and a number of unsuccessful sulphur and oil test wells were drilled before production was obtained. This field places Assumption Parish in the list of the oil-producing parishes of Louisiana.

North Jeanerette, St. Mary Parish.—The producing well, one mile north of the Jeanerette field, found oil at 11,450 ft. Production already has been defined by dry holes 2000 ft. northwest and 1200 ft. east of the discovery well.

North Richie, Acadia Parish.—The discovery well found oil at 8586 ft. in Lower Miocene sands. The field, in which there are now approximately 200 proven acres, is one mile north of the Richie field, where production is obtained from the Upper Miocene section at approximately 3500 feet.

Pecan Island, Vermilion Parish.—The discovery well found gas-condensate at 10,800 ft. Subsequently, a well was drilled one mile northeast, where a new gas-condensate sand was found at 7515 ft., and a well was also drilled 1½ miles west, where another condensate sand was found at 10,279 feet.

Reddell, Evangeline Parish.—The discovery well was completed as an oil well in the Sparta formation at 10,000 ft. This well also tested oil and condensate in the Wilcox. Subsequent development has extended Sparta production one mile eastward. This field is an old geophysical prospect first tested in 1935. Two other tests were also drilled prior to the discovery well into the Cook Mountain formation and the Wilcox. The major structural feature of the field seems to be a large fault extending in a northeast-southwest direction. Two sands are presently producing from the Sparta, which seem to correlate well with the Haas and Tate sands of the Ville Platte field, which is about 12 miles northeast of Reddell.

Rosedale, Iberville Parish.—The discovery well, which originally was drilled to 10,008 ft. in 1939 and abandoned, was reworked and completed as an oil well at 10,000 feet.

St. James, St. James Parish.—The discovery well found gas-condensate at 10,763 ft. Subsequently, a dry hole was drilled ½ mile north of the discovery well, and another test ½ mile south was junked because of an unsuccessful

TABLE 2.—*Wildcat Wells Completed in Louisiana during* 1943

	Parish and Operator	Lease and Well No.	Location			Date Abandoned	Total Depth, Ft.	Abandoned in	Remarks
			Sec.	Tp.	Rge.				
	NORTH LOUISIANA								
	Bienville Parish								
1	Chas. C. Lowrey	A. P. Madden No. 1	3	16 N	8 W	9/11/43	2,110	U. Cre	Chalk series test 3 miles S. of Vacherie salt dome
2	Mid Continent Petr. Corp.	J. R. Jordan No. 1	30	16 N	5 W	11/20/43	7,434	Sligo	4 miles SE. of Bear Creek field
	Bossier Parish								
3	C. W. Beene & Robt. Ehrhardt	Fenet No. 1	25	21 N	14 W	12/ /43	1,002	Nacatoch	Show of oil at 996 ft. (Nacatoch sd.)
4	Bering Oil Co.	Eliz. N. Moresi No. 1	10	22 N	14 W	2/23/43	3,062	U. Cre	
5	Carter Oil Co.	S. H. Bolinger & Co. No. 1	20	22 N	11 W	12/ 1/43	10,000	Cotton Valley	4 miles S. of Carterville-Sarepta field
6	Hunt Oil Co.	Pardee No. A-1	18	23 N	11 W	6/ /43	6,088	Sligo	3 miles SE. of N. Carterville field
7	British American Oil Co.	K. H. Blocker Est. No. 1	1	22 N	13 W	2/ 3/43	6,518	Sligo	Taken over by E. C. Johnson (5-23-43); attempted to complete in "Pettit"; temporarily abd. 8/ /43
8	D. C. Richardson	J. T. Wurtzbaugh et al. No. 1	25	19 N	11 W	12/ /43	6,629	Hosston	1 mile SE. of Bellevue field
9	W. K. Rowe et al.	W. H. Antrim No. 1	22	22 N	13 W	10/ /43	3,101	U. Cre	Temporarily abandoned
10	A. D. Simpson et al.	Fenet No. 1	25	21 N	14 W	7/ /43	1,083	U. Cre	
11	Hugh M. Sneed & A. B. Maynard	Thigpen-Herold No. 1	15	20 N	13 W	9/ /43	3,300	U. Cre	
	Caddo Parish								
12	C. W. Beene	Bostwick et al. No. 1	11	18 N	15 W	1/10/43	1,038	U. Cre	5 miles NW. of Shreveport field
13	Durbin Bond	D. A. Simpson No. 1	17	16 N	16 W	7/19/43	6,172	Hosston	
14	H. C. Owens et al.	Caddo Levee Board No. 1	12	22 N	16 W	6/18/43	1,100	U. Cre	1 mile N. of Vivian area, Caddo-Pine Island field
15	H. C. Owens et al.	Caddo Levee Board No. 1-A	12	22 N	16 W	7/ /43	6,010	Sligo	Pettit test on N. flank of Caddo-Pine Island structure
16	H. C. Owens et al.	Paul Dominick No. 1	7	22 N	14 W	6/ 4/43	6,010	Sligo	"Pettit" test on NE. flank of Caddo-Pine Island structure
17	H. C. Owens et al.	Fuller No. 1	4	22 N	15 W	8/ /43	6,269	Hosston?	Temporarily abd.; "Pettit" test on N. flank of Caddo-Pine Island structure
	Caldwell Parish								
18	R. L. Holcomb	La. Central Oil & Gas Co. No. 1	38	13 N	3 E	2/ 1/43	3,496	Midway	
19	Tom L. Sessions	La. Central Lbr. Co. No. 1	27	12 N	3 E	5/18/43	7,003	Mooringsport	Tuscaloosa test
20	Youngblood-Force	La. Central Lbr. Co. No. 1	18	14 N	3 E	6/ 4/43	6,500	Mooringsport	Tuscaloosa test
	Catahoula Parish								
21	The California Co.	H. C. Eckhardt No. 1	12	9 N	7 E	6/27/43	5,860	Midway	Wilcox test on Sicily Island prospect
22	Sinclair Prairie Co.	State Lease 465 No. 1	30	9 N	7 E	9/28/43	8,700	Mooringsport	Tuscaloosa test on Wallace Ridge prospect
23	Jim McMurrey	H. M. Marks No. 1	11	9 N	8 E	10/27/43	4,620	Wilcox	
24	G. C. Gilger & F. R. Jackson	W. S. Peck No. 1	41	10 N	8 E	3/29/43	5,935	Midway	Wilcox test on Sicily Island prospect
	Claiborne Parish								
25	Benedum-Trees Oil Co.	G. H. Vaughn No. 1	23	23 N	5 W	7/26/43	7,501	Cotton Valley	
26	Gulf Ref. Co., G.P.D.	Frank Miller et al. No. 1	14	20 N	8 W	3/30/43	10,761	Cotton Valley	4 miles SW. of Homer field
27	E. C. Johnston	C. Tims No. 1	12	21 N	7 W	10/ /43	6,009	Hosston	"Pettit" test on NE flank of Homer structure; 3 miles from production
28	F. R. Sylvester	S. P. Meadows No. 1	23	22 N	7 W	2/17/43	6,010	Sligo	4 miles NE. of Homer field

TABLE 2.—(*Continued*)

	Parish and Operator	Lease and Well No.	Location			Date Abandoned	Total Depth, Ft.	Abandoned in	Remarks
			Sec.	Tp.	Rge.				
	Concordia Parish								
29	Gulf Ref. Co., G.P.D. & Danciger Oil & Ref. Co.	H. G. Nelms "A" No. 1	10	1 N	8 E	10/18/43	9,838	Midway	
30	Gulf Ref. Co., G.P.D. & Danciger Oil & Ref. Co.	H. G. Nelms "A" No. 2	68	2 N	8 E	11/29/43	9,409	Midway	
31	Northern Ordinance, Inc.	General American Life Ins. Co. No. 1	9	7 N	7 E	4/ 8/43	6,000	Wilcox	
	De Soto Parish								
32	M. E. Brooks	Jordan Heirs No. 1	9	13 N	14 W	7/22/43	3,100	L. Cre	3 miles NE. of Grand Cane field
33	Crosby Drill. Corp.	W. M. Anders No. 1	5	11 N	14 W	4/26/43	6,327	Hosston	"Pettit" test on Spider anticline
34	Grand Cane Oil & Gas Co.	O'Neal No. 1	24	12 N	15 W	7/ 8/43	5,423	Rodessa	
35	Grand Cane Oil & Gas Co.	Union Central Life Ins. Co. No. 1	22	13 N	14 W	6/ /43	3,100	L. Cre	Temporarily abandoned
36	A. W. Phillips	W. M. Pollock No. 1	8	13 N	12 W	7/ /43	3,100	U. Cre	
	East Carroll Parish								
37	Hunt Oil Co.	Continental Land Co. No. 1	77	22 N	13 E	8/ 3/43	7,076	Jurassic	
	Franklin Parish								
38	C. H. Murphy Jr.	Doris Robinson et al. No. 1	21	13 N	7 E	4/28/43	4,015	Wilcox	
39	Sohio Producing Co.	Mrs. E. E. Splane No. 1	34	12 N	8 E	4/24/43	5,066	Wilcox	
	Grant Parish								
40	Sohio Producing Co.	Colfax Lbr. & Creosoting Co. No. 1	22	8 N	3 W	5/29/43	4,728	Midway	
41	Youngblood-Force	Colfax Lbr. & Creosoting Co. No. 1	8	7 N	3 W	9/21/43	4,975	Midway	
42	Youngblood-Force	Urania Lbr. Co. No. 1	22	7 N	5 W	7/16/43	4,573	Wilcox	
	Jackson Parish								
43	Mid-Continent Petr. Corp.	Tremont Lbr. Co. No. 1	31	15 N	3 W	9/30/43	8,314	Hosston	L. Cretaceous test drilled on Jonesboro prospect
	La Salle Parish								
44	H. L. Hunt	W. E. Harris No. 1	26	11 N	3 E	5/15/43	4,066	Midway	4 miles E. of Standard gas field
	Morehouse Parish								
45	McElreath, Suggett, Roeser & Pendleton, Inc.	Bonita Lbr. Co. No. 1	11	22 N	9 E	7/14/43	6,023	Smackover	Jurassic test on "Monroe uplift"
46	K. E. Merrin et al.	Bonner Memorial No. 1	23	22 N	7 E	1/ 8/43	6,204	Buckner	Jurassic test on "Monroe uplift"
47	Sohio Producing Co.	Carter Oil Co. No. 1	34	19 N	6 E	6/20/43	6,005	Jurassic	Jurassic test on "Monroe uplift"
48	The Texas Co.	Louisville Cooperage Co. No. 1	6	22 N	9 E	12/28/43	5,450	Smackover	Jurassic test on "Monroe uplift"
49	Union Producing Co.	Crossett Tim. & Dev. Co. Unit A-3	5	22 N	6 E	6/11/43	6,225	Jurassic	1 mile NE. of Beekman gas field
50	Union Producing Co.	Crossett Tim. & Dev. Co. No. C-1	9	23 N	6 E	12/ 1/43	6,115	Cotton Valley	4 miles NE. of Beekman gas field
	Natchitoches Parish								
51	Bayou Pierre Oil Co.	B. L. Brown No. 1	25	10 N	8 W	5/ 4/43	1,505	U. Cre	
52	Blackwell Oil & Gas Co.	D. Pardee No. 1	30	12 N	6 W	1/ 7/43	6,510	Rodessa	Black Lake area
53	E. H. Demetrio	Cunningham No. 1	47	10 N	8 W	11/29/43	2,510	U. Cre	
54	O'Meara Bros.	Marble Savings Bank No. 1	42	6 N	5 W	6/15/43	5,200	Wilcox	
55	Howard Youree	Reed No. 1	36	10 N	8 W	4/27/43	3,948	Cretaceous	
	Ouachita Parish								
56	Westgate-Greenland Oil Co. et al.	Louis Werner Sawmill Co. No. 1	9	17 N	2 E	10/ 9/43	6,029	Hosston?	
	Rapides Parish								
57	Moran Oil Co.	Meeker No. 1	6	1 N	1 E	8/17/43	8,142	Wilcox	Le Compte prospect
	Red River Parish								
58	Cryer & Reese	A. M. Adams No. 1	27	12 N	9 W	4/27/43	2,015	U. Cre	
59	Cryer & Reese	Roy Bramburg No. 1	27	12 N	9 W	6/ 4/43	1,991	U. Cre	
60	Cryer & Reese	Long Bell Lbr. Co. No. 1	23	12 N	9 W	2/11/43	2,500	U. Cre	
61	O'Meara Bros.	Franklin Realty Co. No. 1	24	11 N	10 W	3/16/43	3,244	L. Cre	1.5 miles NW. of Lake End field

TABLE 2.—(*Continued*)

	Parish and Operator	Lease and Well No.	Location			Date Abandoned	Total Depth, Ft.	Abandoned in	Remarks
			Sec.	Tp.	Rge.				
62	Haynes B. Ownby Drill. Co.	A. N. Sample No. 1	3	14 N	11 W	3/21/43	6,010	Sligo	
63	Westgate-Greenland Oil Co.	Westdale Corp. No. 1	29	14 N	11 W	3/25/43	3,010	L. Cre	
	Richland Parish								
64	Crown Central Petr. Corp.	D. R. Sartor No. 1	9	16 N	6 E	3/12/43	4,782	Hosston	L. Cretaceous test in center of Richland abd. gas field
	Sabine Parish								
65	Brown-Woods	D. M. Foster et al. No. 1	35	6 N	13 W	1/14/43	4,508	L. Cre	
66	Mid-Continent Petr. Corp.	La. Long Leaf Lbr. Co. No. 1	28	7 N	12 W	12/ /43	5,002	L. Cre	
67	Seaport Oil Corp. & Crosby Drill Corp.	R. J. Lewis No. 1	4	5 N	12 W	8/24/43	3,200	Midway	Negreet area
68	Seaport Oil Corp. & Crosby Drill Corp.	J. K. Phares No. 1	4	5 N	12 W	4/17/43	2,493	Midway	Negreet area
69	Seaport Oil Corp. & Crosby Drill Corp.	J. K. Phares No. 2	4	5 N	12 W	6/15/43	2,503	Midway	Negreet area
	Tensas Parish								
70	Continental Oil Co.	J. D. Trimble et al. No. 1	18	14 N	12 E	1/ 1/43	5,293	Midway	
71	Youngblood-Force	Ayer Timber Co. No. 1	21	14 N	10 E	10/13/43	4,420	Midway	
	Union Parish								
72	H. L. Hunt	Frost Lbr. Co. No. 1	18	23 N	1 E	2/16/43	8,169	Cotton Valley	Jurassic test in old Oakland oil field
	Vernon Parish								
73	W. S. Smith	Nona Mills No. 1	31	3 N	11 W	9/ /43	4,515	Wilcox	
	Webster Parish								
74	R. J. Montgomery et al.	Hortman No. 1	31	20 N	10 W	11/ /43	642	Sparta	Temporarily abandoned
75	J. I. Roberts et al.	J. W. Garland No. 1	24	22 N	9 W	7/24/43	3,025	Brownstown	
76	H. H. Temple	Woodward & Walker No. 1	9	17 N	8 W	4/ /43	1,400	U. Cre	Temporarily abandoned
	West Carroll Parish								
77	Continental Oil Co.	E. L. Bruce Lbr. Co. No. 1	6	20 N	9 E	5/ 1/43	2,640	Hosston?	Core test
78	Continental Oil Co.	E. L. Bruce Lbr. Co. No. 2	4	20 N	9 E	5/16/43	2,682	Hosston?	Core test
79	Continental Oil Co.	E. L. Bruce Lbr. Co. No. 3	2	20 N	9 E	6/ 3/43	2,698	Monroe Gas Rock	Core test
80	Continental Oil Co.	A. G. Causey et al. No. 1	10	20 N	9 E	4/26/43	2,882	Hosston	Core test
81	Placid Oil Co.	J. R. McIntosh No. 1	22	22 N	10 E	12/14/43	5,813	Smackover	
82	R. W. Williams	B. W. Marston, Trust No. 1	14	19 N	10 E	7/ 5/43	2,780	Hosston	1 mile SW. of Epps gas field
	Winn Parish								
83	Mansfield Hdw. Lbr. Co.	Mansfield Hdw. Lbr. Co. No. 1	8	12 N	4 W	5/ 7/43	6,334	L. Cre	2 mile NE. of Calvin gas-condensate field
					SOUTH LOUISIANA				
	Acadia Parish								
84	Sun Oil Co. & Continental Oil Co.	Homeseekers Dev. Co. No. 2	54	10 S	1 W	12/ 8/43	11,962	Vicksburg	Third deep test on Estherwood prospect
	Assumption Parish								
85	Wm. Helis	Armelise Planting Co. No. 1	17	12 S	13 W	1/30/43	10,760	L. Miocene	On SE. flank of Napoleonville dome
	Beauregard Parish								
86	American Republics Corp.	Lutcher-Moore Lbr. Co. No. X-1	3	6 S	13 W	3/13/43	12,455	Wilcox	Wilcox test 1½ mile N. of Bancroft field
87	American Republics Corp.	Lutcher-Moore Lbr. Co. No. X-2	34	5 S	13 W	7/ 3/43	7,060	Cockfield	2 miles N. of Bancroft field
	Calcasieu Parish								
88	Commonwealth Expl. & Drill Co.	Kidder No. 1	11	9 S	12 W	12/ 3/43	5,010	U. Miocene	
89	Union Sulphur Co., Inc.	Burton-Bank No. 1	24	11 S	12 W	5/10/43	9,605	L. Miocene	Gum Cove prospect
90	Union Sulphur Co., Inc.	Stark-Brown No. 1	26	11 S	12 W	8/22/43	9,606	L. Miocene	Gum Cove prospect
91	Union Sulphur Co., Inc.	Stark-Brown No. 2	35	11 S	12 W	12/28/43	9,100	L. Miocene	Gum Cove area
92	Union Sulphur Co., Inc.	Ulrich No. 6	19	9 S	10 W	9/ 5/43	7,841	L. Miocene	¾ mile NW. of Sulphur Mines dome

TABLE 2.—(*Continued*)

	Parish and Operator	Lease and Well No.	Location			Date Abandoned	Total Depth, Ft.	Abandoned in	Remarks
			Sec.	Tp.	Rge.				
93	W. T. Burton	Lutcher-Moore Lbr. Co. No. 9	17	9 S	12 W	6/ 4/43	9,575	Vicksburg?	On NE. flank of Stark's dome 3000 ft. from production
94	W. T. Burton	Erwin Estate Heirs No. 1	17	11 S	8 W	11/29/43	12,042	Vicksburg?	South Lake Charles prospect
	Cameron Parish								
95	Jack Frazier	Sweet Lake Land & Oil Co. No. 1	12	12 S	7 W	2/25/43	8,954	U. Miocene	
96	Magnolia Petr. Co.	R. A. Moore No. 1	13	12 S	12 W	10/27/43	10,808	Vicksburg	Gum Cove area
	East Baton Rouge Parish								
97	A. J. Bankhead & T. G. Markley	McInnis No. 1	58	7 S	1 E	1/30/43	7,536	L. Miocene	
	Iberia Parish								
98	The Texas Co.	State Lse. 340, Rabbit Island No. 4		Gulf		2/24/43	9,838	U. Miocene	6800 ft. NE. of only producing well in Rabbit Island field
99	The Texas Co.	State Lse. 340, Rabbit Island No. 5		Gulf		10/ 7/43	9,930	U. Miocene	5200 ft. E. of only producing well in Rabbit Island field
100	The Texas Co.	State Lse. 334, Vermilion Bay No. C-1		14 S	6 E	12/20/43	11,866	U. Miocene	South Tigre Lagoon prospect
	Jefferson Parish								
101	The California Co.	Bailey et al., Unit 119 No. 1	2	16 S	13 E	10/ 3/43	11,058	U. Miocene	1 mile NE. of production at Barataria field
102	The Texas Co.	Lafourche Basin Levee District No. A-4	34	19 S	24 E	5/13/43	9,701	U. Miocene	1¼ mile SE. of production on Bay de Chene dome
	Jefferson Davis Parish								
103	Cities Service Oil Co.	D. J. Benoit No. 1	25	11 S	5 W	9/11/43	11,274	L. Miocene	1 mile N. of discovery well, Thornwell field
104	Continental Oil Co.	Mrs. F. B. Hopson No. 1	31	10 S	4 W	3/28/43	11,282	L. Miocene	1 mile NE. of Nibletts field
	Lafourche Parish								
105	Amerada Petr. Corp.	David Guidroz et al. Unit No. 1	35	16 S	19 E	4/29/43	9,871	U. Miocene	1 mile S. of production at Raceland field
106	Amerada Petr. Corp.	C. E. Gheens No. 10	56	15 S	20 E	11/14/43	10,701	U. Miocene	1 mile S. of production at Bayou des Allemands
107	The Atlantic Ref. Co.	Allen Land Co. No. 1	49	19 S	22 E	1/ 5/43	5,988	U. Miocene	2½ miles E. of Golden Meadow field
108	Gulf Ref. Co. (G.P.D.)	Delta Securities Co. No. 3	53	19 S	21 E	6/12/43	8,425	U. Miocene	On SE. flank of Bully Camp dome 1 mile SE. of production
109	Pan American	Citizens Bank & Trust Co. No. 1	102	17 S	20 E	11/ 3/43	10,357	L. Miocene	3100 ft. E. of production at Valentine dome
	Livingston Parish								
110	Danciger Oil & Ref. Co.	McGreevy No. 1	1	8 S	6 E	1/ 9/43	7,415	L. Miocene	Second well on Tickfaw prospect
	Orleans Parish								
111	W. T. Burton	State Lse. 318, Lake St. Catherine No. 9		11 S	14 E	6/10/43	9,896	L. Miocene	
	St. Charles Parish								
112	L. J. Roussel	Ellington No. 1	119	13 S	20 E	1/ 8/43	4,500	U. Miocene	
	St. James Parish								
113	George Echols	Realty Operators, Inc. No. 1	19	12 S	17 E	4/22/43	8,792	U. Miocene	On SE. flank of Hester dome, 1 mile SE. of production
	St. Landry Parish								
114	J. S. Abercrombie & Atlat. Royalty Corp.	A. Charles et al. Unit 2 No. 1	23	7 S	5 E	5/26/43	10,220	Vicksburg	South Leonville prospect
115	J. S. Abercrombie & Atlat. Royalty Corp.	Stelly et al. Unit 9 No. 1	23	7 S	5 E	10/31/43	10,443	Jackson	South Leonville prospect
	St. Martin Parish								
116	George Echols	Alexis Voorhies No. 1	72	9 S	5 E	3/23/43	10,519	L. Miocene	SE. flank Anse la Butte dome, 150 ft. SE. of abd. producing well
117	George Echols	E. L. St. Germain No. 1	114	9 S	5 E	3/ 1/43	10,383	L. Miocene	E. flank of Anse la Butte dome, NE. of abd. producing well
118	Amerada Petr. Corp.	Jeanerette Lbr. & Shingle Co. No. 1	24	11 S	9 E	7/21/43	11,980	U. Miocene	4000 ft. W. of production at Lake Chicot field

TABLE 2.—(*Continued*)

	Parish and Operator	Lease and Well No.	Location			Date Abandoned	Total Depth, Ft.	Abandoned in	Remarks
			Sec.	Tp.	Rge.				
	St. Mary Parish								
119	Arkansas Fuel Oil Co...	Shadyside Co. No. 1	5	15 S	10 E	4/19/43	12,020	U. Miocene	
120	Sun Oil Co...........	Belle Isle Corp. No. 3	1	18 S	10 E	5/26/43	4,096	Salt	S. flank of Belle Isle dome, ¾ mile W. of production
121	Sun Oil Co...........	State Lse. 350, Belle Isle Corp.	19	17 S	11 E	1/15/43	11,011	U. Miocene	NE. flank Belle Isle dome, 3000 ft. salt overhang
122	Sun Oil Co...........	State Lse. 350, Belle Isle Corp.	28	17 S	10 E	2/26/43	4,060	Salt	N. flank Belle Isle dome, 1¼ mile N. of production
123	The Texas Co.........	State, Cote Blanche Island No. 4		15 S	7 E	5/14/43	8,540	Salt	SE. flank of Cote Blanche Island dome
	Terrebonne Parish								
124	Duvall Texas Sulphur Co.	Louisiana Land & Expl. Co. No. 1	23	21 S	16 E	5/15/43	1,315	Salt	Sulphur test on Four Island Bay dome
125	Duvall Texas Sulphur Co.	Louisiana Land & Expl. Co. No. 2	23	21 S	16 E	6/26/43	1,920	Salt	Sulphur test on Four Island Bay dome
126	Duvall Texas Sulphur Co.	Louisiana Land & Expl. Co. No. 3	24	21 S	16 E	7/30/43	1,330	Salt	Sulphur test on Four Island Bay dome
127	Humble Oil & Ref. Co.	Continental Land & Fur Co. No. B-2	25	17 S	13 E	6/ 7/43	11,273	U. Miocene	Third dry test on Turtle Bayou prospect
128	Humble Oil & Ref. Co.	Continental Land & Fur Co. No. C-1	4	18 S	15 E	8/ 8/43	11,540	U. Miocene	Bayou Cocodrie prospect
129	Humble Oil & Ref. Co.	LaTerre Co., Inc. No. B-1	81	18 S	18 E	5/16/43	11,281	U. Miocene	1 mile W. of production at South Houma field
130	The Texas Co.........	State Lse. 200, Dog Lake No. 13		21 S	16 E	12/27/43	11,648	U. Miocene	On N. flank Dog Lake dome 1¼ mile N. of production
131	The Texas Co.........	L. L. & E., Bay St. Elaine No. 5	24	22 S	17 E	12/17/43	12,689	U. Miocene	4000 ft. S. of production at Bay St. Elaine dome
132	Union Oil Co. of California..............	Calvert & Todd No. 1	16	17 S	17 E	7/22/43	12,009	U. Miocene	
	West Baton Rouge Parish								
133	Amerada Petr. Corp...	Harry B. Nelson et al. No. 1	97	7 S	12 E	4/22/43	10,100	L. Miocene	

"fishing job" after the well had penetrated a possible productive zone.

Shuteston, St. Landry Parish.—The discovery well found gas-condensate at 9500 ft. Production subsequently was defined by a dry hole ¼ mile north of the discovery well.

White Lake, Vermilion Parish.—The discovery well tested three gas-condensate sands found at 8356, 10,618 and 10,660 ft. The well is presently shut in.

During the year, 362 field wells were drilled in south Louisiana. Of this number, 252 were completed as oil wells, 19 as gas wells, and 91 were dry. In the process of drilling and completing these wells, 28 oil sands and 14 gas sands were found and put to production. The more important of these developments are listed briefly in the following paragraphs:

Avery Island, Iberia Parish.—Productive band on the southwest flank of the dome has been established, and drilling is following this trend.

Bastian Bay, Plaquemines Parish.—A dry test (10,802 ft.) was drilled ¼ mile north of production on the northwest flank of this field.

Bayou Bleu, Iberville Parish.—Dry holes were drilled on the northwest flank (8110 ft.), the south flank (5293 ft.) and the northeast flank. The latter encountered salt at 6762 feet.

Bayou Couba, St. Charles Parish.—The discovery well of this field (completed in 1942) was abandoned in March 1943. This field was rediscovered in April from the same sand, ¼ mile east of the discovery well. A test well ¼ mile north of the rediscovery well was abandoned as dry after topping salt at 6360 feet.

Bayou Sale, St. Mary Parish.—An 11,300-ft. dry test was drilled one mile east of production. Subsequently, a completion was made midway between the dry test and production.

Belle Isle, St. Mary Parish.—A 4060-ft. wildcat test 1¼ miles from production on the north flank and an 11,011-ft. semiwildcat test on the northeast flank one mile from production were abandoned as dry. The 11,011-ft. test penetrated a 3000-ft. salt overhang. A third dry test (4096 ft.) was drilled on the south flank one mile west of production.

Black Bayou, Cameron Parish.—A new Upper Miocene oil sand was discovered on the northeast flank of the dome, about ¼ mile southeast of the north flank (Lower Miocene) production, and about ½ mile northwest of the southeast flank (Upper Miocene) producing area.

Branch, Acadia Parish.—A new condensate sand discovered at 9900 feet.

Bully Camp, Lafourche Parish.—Nineteen sulphur tests drilled into cap rock (1700 to 2500 ft. deep). One was completed in a new gas sand at 1100 ft. A wildcat well (8425 ft.), drilled one mile southeast of the gas-discovery well, was dry and abandoned.

Caillou Island, Terrebonne Parish.—New gas sand found at 8200 ft. in well 4000 ft. southwest of production. New oil sand found at 11,100 ft. in well 4000 ft. east of production.

Cameron Meadows, Cameron Parish.—Two dry test wells, 7000 and 8000 ft., respectively, were drilled on the east flank of the dome approximately 600 ft. east of nearest producing well.

Chacahoula, Lafourche Parish.—Production was extended ½ mile on southwest flank. New oil sand discovered at 4230 ft. on southeast flank. A new gas-condensate sand at 8650 ft. was discovered on same flank and extended production 4000 ft. to the east. Three shallow tests on southwest flank were abandoned as dry.

Chalkley, Cameron Parish.—Two semiwildcat wells about ¾ mile northwest of producing area were abandoned as dry at 8305 and 8414 feet.

Cheneyville, Rapides Parish.—Dry hole (5798 ft.) drilled ½ mile northwest of production.

Deer Island, Terrebonne Parish.—A semiwildcat one mile southeast of production blew out and was abandoned at a total depth of 11,350 ft. Condensate production was extended one mile north.

Delacroix, Plaquemines Parish.—New oil sand discovered at 9600 ft. on the northeast flank ¼ mile from production.

Delarge, Terrebonne Parish.—World's deepest producing well was completed and shut in. This well, Union Producing Company's Fitzpatrick and Vizard et al. Unit No. 1 well, was drilled ½ mile east of production to a total depth of 13,563 ft., and completed in a condensate sand at 13,475 to 13,490 ft. It is reported that the producing sand is the same as that producing in the discovery well but is 275 ft. structurally higher.

Delta Farms, Lafourche and Jefferson Parishes.—New gas sand at 9700 ft. discovered on east flank. Field extended ½ mile northwest.

Dog Lake, Terrerbonne Parish.—Dry hole (9539 ft.) ½ mile southeast of production.

East Hackberry, Cameron Parish.—Old pumping well (The Texas Company's State Lease No. 50, No. 20) on northeast flank of dome began flowing 2400 bbl. of fluid daily (50 per cent pipe-line oil).

East White Lake, Vermilion Parish.—Three wells dually completed in 5900 and 6400-ft. sands.

Eola, Avoyelles Parish.—Five wells formerly producing from the Wilcox have been recompleted in the Sparta sand.

Erath, Vermilion Parish.—Thirty-two wells have been completed during the year. Most of the wells are shut in awaiting completion of the cycling plant. Fourteen of the 27 wells are dually completed wells.

Four Isle Bay, Terrebonne Parish.—Three unsuccessful sulphur test wells (1330 to 1900 ft. deep) were drilled.

Golden Meadow, Lafourche Parish.—Dry holes were drilled ½ mile north (11,972 ft.) and ½ mile west (4006 ft.) of production on west flank.

Grand Bay, Plaquemines Parish.—A dry test on southwest flank ½ mile from production was abandoned at 10,010 feet.

Hayes, Calcasieu Parish.—Second well completed, extending production ½ mile northwest.

Hester, St. James Parish.—A dry test (9492 ft.) was drilled on the southeast flank one mile from production; new gas-condensate sand found at 9350 ft. one mile southwest of production; new oil sand found at 5300 ft. in a well on east side of Mississippi River; latter topped salt at 7675 ft. New gas-condensate sand also found at 10,550 ft. in a well 1.6 miles north of production; latter topped salt at 10,700 feet.

TABLE 3.—*Discovery Wells in Louisiana*, 1943

Field and Parish	Operator, Lease and Well No.	Location			Completion Date	Total Depth, Ft.	Producing Depth, Ft.	Initial Production Data							Geologic Age of Production
								Daily Rate		Choke, In.	B.S. and W., Per Cent	Gravity, A.P.I. at 60°F.	Gas-oil Ratio, Cu. Ft. per Bbl.	Tubing Pressure, Lb. per Sq. In.	
		Sec.	Tp.	Rge.				Bbl.	M. Cu. Ft.						
NORTH LOUISIANA															
East Nebo, *La Salle*...	Geo. H. Echols, Kendrick No. 1	7	7 N	4 E	8/26/43	5,208	3,896– 3,900	92		1/8	13	37°	1,055/1	330	Wilcox
Holly Ridge, *Tensas*...	Carter Oil Co., R. D. Shelly No. 1	19	11 N	10 E	8/ 9/43	8,444	8,399– 8,410	280		5/32	Tr.	37.5°	915/1	1,500	Tuscaloosa
Lucky, *Bienville*.......	Placid Oil Co., Nebo Oil Co. No. A-1	11	15 N	7 W	3/ 3/43	7,804	6,836– 6,864		2,000		0.1			3,000	Sligo
North Cotton Valley, *Webster*	Ohio Oil Co., W. T. Gleason No. 1	31	22 N	9 W	11/ 6/43	8,648	8,452– 8,482	293	4,026	16/64	0	63.3°	13,721/1	2,550	Cotton Valley
North Lake St. John, *Tensas*	Carter Oil Co., Grace Rhodes No. 2	28	9 N	10 E	5/ 6/43	6,017	4,435– 4,442	345		24/64	5	40.4°	250/1	500	Wilcox
Northwest Ruston, *Lincoln*	Ark. La. Gas Co., W. F. Stiles No. 1	19	19 N	2 W	10/26/43	5,989	5,878– 5,896		45,000					2,400[1]	Hosston
SOUTH LOUISIANA															
Arnaudville, *St. Martin*	Amerada Petr. Corp., Bertinot-Quebedeaux No. 1	44	7 S	5 E	12/ 4/43	10,700	10,349–10,378	69	791	10/64	0.1	42.6°	11,300/1	3,700	L. Mio
Bear, *Beauregard*......	General Crude Oil Co., C. S. Baldwin No. 1	27	6 S	9 W	9/ 3/43	9,414	6,512– 6,520	151		8/64	0.1	43.6°		1,200	L. Mio
Big Lake, *Cameron*[2]....	Continental Oil Co., A. Hebert No. 1	18	12 S	8 W	9/15/43	12,926	8,571– 8,586	140		8/64				2,650	U. Mio
East Gibson, *Terrebonne*	Falcon-Seaboard Drilling Co. & William Helis Co., Jackson Est. No. 1	25	17 S	15 E	10/28/43	10,600	9,280– 9,290	275	138	8/64	0.1	33.7°	500/1	1,200	U. Mio
Egan, *Acadia*.........	Sun Oil Co. & Standard Oil Co. of Ohio, J. R. Dailey et al. No. 1	31	9 S	1 W	5/ 6/43	11,199	10,610–10,625	105	3,550	12/64	0	50.6°	33,800/1	3,640	L. Mio
Fields, *Beauregard*.....	Sohio Prod. Co., Lutcher-Moore Lbr. Co. No. 1	34	6 S	12 W	9/16/43	10,912	8,011– 8,020	182	3,508	16/64				2,250	Cockfield
Hope Villa, *East Baton Rouge*	Shamrock Oil & Gas Co., L. P. Phillips No. 1	44	8 S	2 E	9/ 1/43	9,874	9,568– 9,575	339	88	10/64	0.1	45.4°	260/1	1,010	L. Mio

[1] Rock pressure.

[2] Rediscovery.

TABLE 3.—(*Continued*)

Field and Parish	Operator, Lease and Well No.	Location			Completion Date	Total Depth, Ft.	Producing Depth, Ft.	Initial Production Data							Geologic Age of Production
		Sec.	Tp.	Rge.				Daily Rate		Choke, In.	B.S. and W., Per Cent	Gravity, A.P.I. at 60°F.	Gas-oil Ratio, Cu. Ft. per Bbl.	Tubing Pressure, Lb. per Sq. In.	
								Bbl.	M. Cu. Ft.						
Napoleonville, *Assumption*	Geo. Echols, Kessler & Sternfels No. 1	136	12 S	14 E	1/25/43	10,474	9,034– 9,039	130	745	7/64	0.1	37.5°	650/1	1,200	U. Mio
North Jeanerette, *St. Mary*	Atlantic Ref. Co., Adeline Sugar Factory No. 1	19	13 S	9 E	5/24/43	12,211	11,457–11,462	292	234	9/64	0.1	34.6°	800/1	2,000	U. Mio
North Richie, *Acadia*..	Continental Oil Co., Acadia Parish School Land No. 1	16	7 S	1 W	7/26/43	9,909	8,586– 8,591	81	420	7/64	0.1	37.7°	5,185/1	2,425	L. Mio
Pecan Island, *Vermilion*	Humble Oil & Ref. Co., Louisiana Furs Inc. No. 1	34	16 S	1 E	2/ 2/43	12,057	10,832–10,853	10	730		0.1	50.8°	73,080/1	4,150	U. Mio
Reddell, *Evangeline*....	Continental Oil Co. & Humble Oil & Ref. Co., Pardee Lbr. Co. No. 3	20	4 S	1 W	11/10/43	11,589	9,960–10,000	159		9/64	Tr.	57°	6,380/1	1,050	Sparta
Rosedale, *Iberville*.....	Sugarfield Oil Co., Wilbert No. 1	74	7 S	10 E	10/28/43	10,533	10,009–10,012	215	194	7/64	0.5	34.7°	900/1	1,620	L. Mio
St. James, *St. James*...	Humble Oil & Ref. Co., Panno & Bosetta No. 1	8	12 S	16 E	4/17/43	10,895	10,763–10,785	96	2,520	12/64	0	51.6°	26,250/1	3,830	U. Mio
Shuteston, *St. Landry*..	Sun Oil Co., A. T. Burleigh "Pool" No. 1	37	7 S	4 E	3/ 6/43	11,513	9,495– 9,505	146	270	8/64	0.1	37.1°	1,849/1	1,600	L. Mio
South Lewisburg, *Acadia*	Amerada Petr. Corp., C. D. Daigle No. 1	75	7 S	3 E	8/31/43	10,504	10,306–10,353	149	2,211	10/64		60°	14,840/1	3,550	L. Mio
West White Lake, *Vermilion*	Union Oil Co. of California, State Lse. No. 540, White Lake No. 1-A	In Lake	14 S	2 W	12/31/43	12,000	10,660–10,675	Shut in							U. Mio

Jefferson Island, Iberia Parish.—A new oil sand discovered at 9500 ft. on east flank 1000 ft. east of production.

Jennings, Acadia Parish.—The Clements sand (the deepest producing horizon) was extended ½ mile southeast on the south flank. Two tests on the north flank were dry and abandoned.

Lake Arthur, Jefferson Davis Parish.—Lower Miocene test (9252 ft.) drilled approximately ½ mile northeast of present production was dry.

Lake Chicot, St. Martin Parish.—Dry hole ¼ mile northeast of production was abandoned at 11,980 ft.; new oil sands found at 7700 and 10,200 feet.

Lake Decade, Terrebonne Parish.—Production extended ½ mile east. Dry test (12,802 ft. deep) was drilled ½ mile north of latter extension.

Lake Pelto, Terrebonne Parish.—A new oil sand at 7700 ft. discovered on the southwest flank; new oil sand also found at 11,000 ft. on southeast flank.

La Pice, St. James Parish.—Production was extended ½ mile southwest in the 7700-ft. sand; new oil sand discovered at 10,130 feet.

Leeville, Lafourche Parish.—Gas sand at 2930 ft. discovered on northeast flank. Three oil sands were discovered on the southwest flank at 8025, 9800, and 10,000 feet.

Lirette, Terrebonne Parish.—The 10,500-ft. gas sand was extended ½ mile south on the east flank in a well that after cutting fault was structurally high.

Neale, Beauregard Parish.—Lower Wilcox producing area extended ¾ mile east and 1½ miles west. Two wells, completed in 1942, were dually completed, and one Upper Wilcox dry hole (temporarily abandoned 1940) was deepened for Lower Wilcox production. Three new sands were put to production.

Northeast Gibson, Terrebonne Parish.—Producing sand in the Northeast Gibson and the Gibson fields has been joined. Apparently only a very shallow "saddle" occurs between these two fields.

North Jeanerette, St. Mary Parish.—Test well 2000 ft. northwest of discovery well was abandoned at 12,041 ft.; an 11,660-ft. dry test was drilled 1200 ft. east of the discovery well.

Paradis, St. Charles Parish.—One dry well (10,502 ft.) drilled on the east flank in low part of graben. With the exception of Erath and Vinton, this field was one of the most active in south Louisiana.

Pine Prairie, Evangeline Parish.—Sparta production (discovered 1942) extended ½ mile westward on south flank. Two new Sparta oil sands discovered in 1943 at 7900 and 9000 ft. Wilcox production discovered on west flank of dome and later extended 600 ft. northeastward and 2000 ft. south; one well encountered salt on south flank at 4878 feet.

Rabbit Island, Iberia Parish.—Two semiwildcat wells, one 6800 ft. northeast and one 5200 ft. east of the discovery well, were abandoned as dry.

Raceland, Lafourche Parish.—Production limited by 9871-ft. test ½ mile south of production.

Roanoke, Jefferson Davis Parish.—Production extended about ¼ mile on northwest flank; 7000-ft. dry hole drilled 1000 ft. east of producing area, and 8530-ft. dry hole drilled ½ mile southeast of producing area.

St. Gabriel, Iberville Parish.—A new condensate sand at 9700 ft. was discovered ½ mile west of production. This sand was defined by a dry hole ¼ mile south of the discovery well. A new oil sand was discovered on the south flank in a well drilled and abandoned as dry in 1939. Well completed as pumper, 5 bbl. per day.

Starks, Calcasieu Parish.—Test well drilled on southeast flank, about 2000 ft. southeast of old shallow producing area, abandoned in salt at 3451 ft.; 3557-ft. test drilled on southwest flank about 1700 ft. south of producing area also abandoned.

University, East Baton Rouge Parish.—Production extended 2000 ft. east in deep pay zones below 9000 ft. in area proven nonproductive in shallow sands. In the old producing area a new gas sand at 5550 ft. was initially produced.

Unknown Pass, Orleans Parish.—Both producing wells abandoned.

Valentine, Lafourche Parish.—First deep test (10,357 ft.) on the east flank 3000 ft. from production was abandoned as dry.

Ville Platte, Evangeline Parish.—Wilcox producing area extended approximately one mile on northeast, north, and northwest flanks of field; more closely defined on south flank;

Sparta producing area extended on northwest flank approximately ½ mile.

Vinton, Calcasieu Parish.—One of the most active fields in south Louisiana during 1943; 17 wells drilled on north flank of dome (north flank, Lower Miocene production discovered 1942), of which 16 found oil, and one, a semiwildcat (6853 ft. in depth), drilled about ½ mile northeast of the presently producing area, was abandoned as dry. North flank producing area now covers approximately 160 acres. Four new oil sands were discovered in 1943.

Welsh, Jefferson Davis Parish.—New gas-condensate sand discovered at 8900 ft. on northwest flank of dome about one mile northwest of old shallow producing area.

West Bay, Plaquemines Parish.—New oil sand at 10,775 ft. discovered on northwest flank in a well that extended production ⅓ mile.

West Hackberry, Cameron Parish.—Three new dual completions, plus four old wells, recompleted as dual completions during 1943.

West Mermentau, Jefferson Davis Parish.—Producing area extended ¼ mile southeast and defined by a 10,885-ft. test on the southwest.

White Castle, Iberville Parish.—A new oil sand at 9300 ft. was discovered on the west flank.

WILDCAT WELLS

During the year, 156 wildcat, or exploratory, wells were drilled, as compared with 178 during 1942. However, only 11.4 per cent were successful during 1942 and 14.7 per cent were successful during 1943. The apparent value, as far as reserves are concerned, discovered by these wildcat wells is approximately the same for both years. In all, 89 wildcat wells were drilled in north Louisiana during the past year. Of this total, 21 wells tested the Wilcox, 24 the Upper Cretaceous, 25 the Lower Cretaceous, 12 the Jurassic, and one was temporarily abandoned in the Sparta formation. In south Louisiana, 67 wildcat wells were drilled. Of this number, 22 were abandoned in the Upper Miocene, 14 in the Lower Miocene, five in the Vicksburg, one in the Jackson, one in the Claiborne, one in the Wilcox, and six were abandoned in salt plugs.

ACKNOWLEDGMENTS

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Oil and Gas Development in Michigan during 1943

By Theron Wasson,* Member A.I.M.E.

The oil and gas fields of Michigan that have been under development since 1925 are in an area that extends across the middle of the lower peninsula from northeast to southwest, a distance of about 200 miles, and with a width of about 80 miles. In 19 years 70 fields have been discovered. Most of these are relatively small when compared with other oil-producing areas. This is borne out by the fact that since the first wells were drilled these fields have produced a total of only 204,000,000 bbl. However, Michigan is still maintaining its production, for during the past five years the annual production has remained fairly constant at approximately 20,000,000 bbl. Production for 1943, as reported by the Bureau of Mines, was 20,682,000 barrels.

Roughly, one third of Michigan's production in 1943 came from the Reed City field, which was discovered in 1941. During the year, 237 oil wells were completed in Michigan in 1943. The decrease of 56 from the 1942 total is probably due to the continuance of Government regulations requiring a 40-acre spacing pattern over most of the state.

Fig. 1 shows the principal oil and gas fields of Michigan, and the columnar section, Fig. 2, shows the principal producing horizons in relation to the section drilled. The data of Table 1 and Table 2 have been carefully checked with previous reports to eliminate errors.

New Discoveries and New Developments

Six new producing areas were discovered during 1943 and five areas discovered in 1942 were developed during the year. Both the new discoveries and the 1942 discoveries that were developed appear to be small and relatively unimportant.

Goodwell Field.—The best discovery of the year is the Goodwell field, T. 14 N., R. 11 W., Goodwell township, Newaygo County. This small structure was located by core testing done by The Pure Oil Co. in 1942 and early 1943. The first producing well, C. R. Harris No. 1, was completed on July 5, 1943, in the Traverse limestone at a total depth of 2742 ft., with an estimated potential of 1100 bbl. per day. By the end of the year, 18 wells had been completed in this field and approximately 281,000 bbl. of oil produced. The field operated under proration of 262 bbl. per day per well from Oct. 1 to Dec. 1; 150 bbl. per day per well after that date.

Woodville Field.—The small Woodville pool, T. 15 N., R. 11 W., 3 miles north of the Goodwell field, was discovered by core testing by the Ohio Oil Co. The discovery well was completed on May 5, 1943, flowing 650 bbl. of fluid, including 18 per cent salt water the first 18 hr., from the Traverse limestone at a depth of 2810 to 2815 ft. Seven wells had been completed by the end of the year and 67,000 bbl. of oil had been produced. Development is now practically at a standstill because further drilling does not appear economically justified.

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Rose Lake Field.—Discovered by a wildcat venture of the Union Drilling Co. completed on July 8, 1943, the importance of the Rose Lake field is still hard to evaluate. The discovery well was located in sec. 31, T. 19 N., R. 9 W., and production has now spread into the adjacent three townships. Eight wells had been completed by the end of the year and 75,000 bbl. of oil produced. Production is from the Traverse limestone at a depth of approximately 3150 ft. Production to date has been complicated by the occurrence of salt water in some of the wells and by excessively high oil-gas ratios in others.

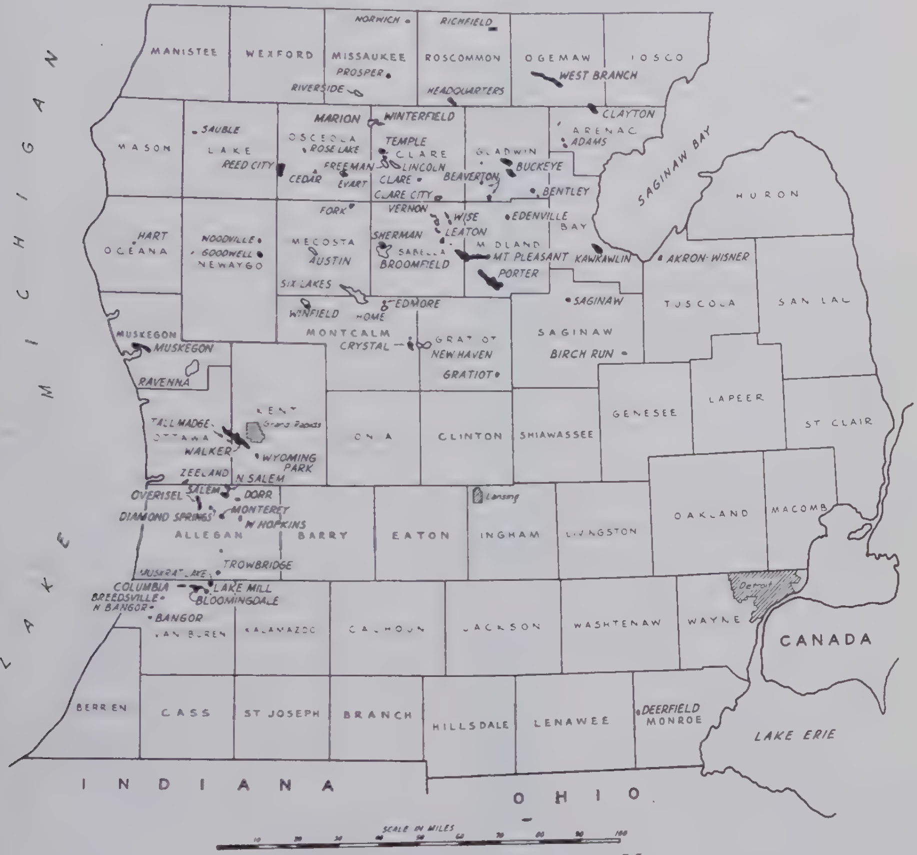

FIG. 1.—PRINCIPAL OIL AND GAS FIELDS OF MICHIGAN.

Breedsville Field.—Near Breedsville, Van Buren County, T. 1 S., R. 16 W., nine wells have found minor production in the Traverse lime at a depth of 1050 ft. The discovery well was drilled by William H. Clock and was completed on Feb. 13, 1943, with an initial production of 50 bbl. per day. A total of 60,000 bbl. of oil was produced in 1943.

Hatton Field.—The Hatton "field," sec. 31, Hatton township, Clare County, T. 18 N., R. 4 W., was represented at the end of 1943 by two prolific producers and three offsetting dry holes. The discovery well was drilled by Ranch Oil Co. and was completed Aug. 2, 1943, for an estimated 7200 bbl. per day. A total of 42,000 bbl. of oil was produced. Production

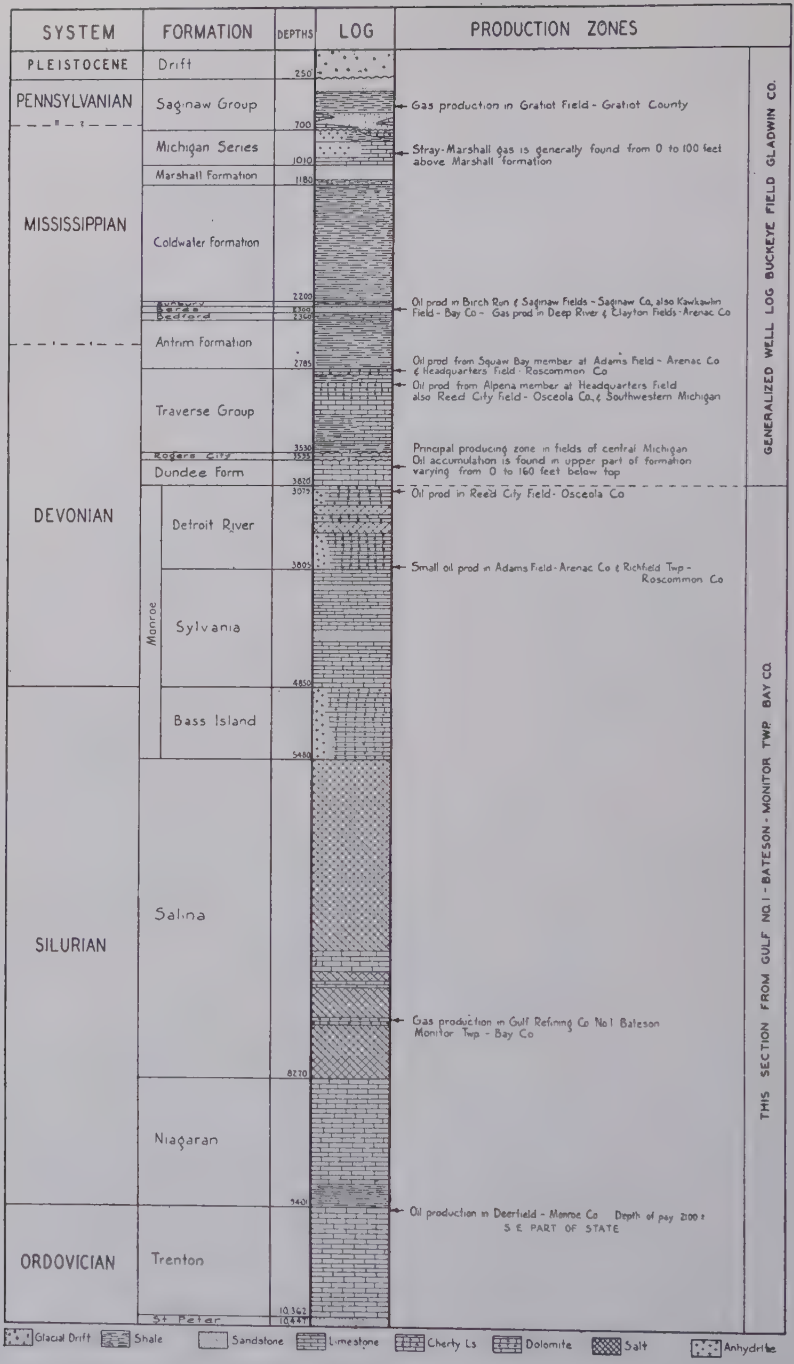
SYSTEM
FORMATION
DEPTHS
LOG
PRODUCTION ZONES
PLEISTOCENE
Drift
250'
PENNSYLVANIAN
Saginaw Group
Gas production in Gratiot Field - Gratiot County
700
MISSISSIPPIAN
Michigan Series
Stray-Marshall gas is generally found from 0 to 100 feet above Marshall formation
1010
Marshall Formation
1180
Coldwater Formation
2200
Sunbury
Berea
Bedford
2300
2360
Oil prod in Birch Run & Saginaw Fields - Saginaw Co, also Kawkawlin Field - Bay Co - Gas prod in Deep River & Clayton Fields - Arenac Co
Antrim Formation
2785
Oil prod from Squaw Bay member at Adams Field - Arenac Co & Headquarters Field · Roscommon Co
Oil prod from Alpena member at Headquarters Field also Reed City Field - Osceola Co, & Southwestern Michigan
DEVONIAN
Traverse Group
3530
3535
Rogers City
Principal producing zone in fields of central Michigan
Oil accumulation is found in upper part of formation varying from 0 to 160 feet below top
Dundee Form
3820
3079
Oil prod in Reed City Field - Osceola Co
Detroit River
3805
Small oil prod in Adams Field - Arenac Co & Richfield Twp - Roscommon Co
Monroe
Sylvania
4850
Bass Island
5480
SILURIAN
Salina
Gas production in Gulf Refining Co No 1 Bateson Monitor Twp - Bay Co
8270
Niagaran
9401
ORDOVICIAN
Trenton
Oil production in Deerfield - Monroe Co Depth of pay 2100 ± S E PART OF STATE
10,362
10,447
St Peter
GENERALIZED WELL LOG BUCKEYE FIELD GLADWIN CO.
THIS SECTION FROM GULF NO. 1 - BATESON - MONITOR TWP. BAY CO.
Glacial Drift
Shale
Sandstone
Limestone
Cherty Ls
Dolomite
Salt
Anhydrite

FIG. 2.—PRINCIPAL PRODUCING HORIZONS.

is from the Dundee at a depth of 3962 ft. Development work is still in progress but there is little evidence that an important field is in sight.

Fillmore Field.—The Fillmore "field," in Secs. 2, 3, 11, and 12, T. 4 N., R. 15 W., Fillmore township, Allegan County, represents a minor accumulation in the Traverse limestone at a depth of 1540 ft. The discovery well was completed on June 10, 1943, by J. W. Lang et al. Five wells have been drilled to date and 13,000 bbl. of oil produced. There is little evidence that the field can become important, though additional drilling is in progress.

DEVELOPMENT IN OLD FIELDS

The Prosper field in Missaukee County, the North Bangor field in Van Buren County, the South Zeeland field in Ottawa County, and East Norwich field in Roscommon County, all 1942 discoveries, were developed during 1943. In all, 41 wells were drilled in the four areas during the year. Collectively, 651,000 bbl. of oil were produced, nearly two thirds of which came from the now fully developed 13-well Prosper field.

Of much more importance was the continued development of the Fork field, Mecosta County. At the end of 1942, three wells had been completed; during 1943, 33 more wells were added, and development was still in progress at the end of the year. A total of 798,000 bbl. of oil was produced in 1943.

WILDCAT DRILLING

Wildcat drilling decreased as compared with previous years. All of the drilling was to already known producing horizons. At the end of the year several tests were under way in the southeastern part of the state in the area west of Detroit, where large blocks have been taken. It is understood that the tests in this area will go into the Cambrian rocks, which heretofore have not been explored in Michigan.

EXPLORATION

Since the Michigan Basin is covered by a blanket of glacial drift, in places as much as 1000 ft. thick, the principal method of exploration for new fields has been by means of shallow holes drilled to the bedrock beneath the drift to determine structural conditions. Shallow testing of this kind showed an increase for 1943 over that done in the previous year; 302 permits were issued by the Department of Conservation for the drilling of shallow holes. The greatest activity in the leasing of new drilling blocks was in the Thumb area east of Saginaw Bay, where one company did seismograph work.

PRORATION

All flush production has been operated under State proration throughout the year, as follows, for 20-acre and 40-acre drilling units:

Field	Jan. 1	Feb. 1	June 1	Oct. 1	Dec. 16
Adams	150–262	150–262	150–262	150–262	150–262
Headquarters	150–262	150–262	125–218	125–218	125–218
Evart		150–262	150–262	86–150	86–150
Fork		150–262	150–262	86–150	86–150
Goodwell				262	150
Prosper			150–262	86–150	86–150
Reed City	150–262	150–262	125–218	125–218	100–175
Rose Lake				150–262	150–262
Winterfield	150–262	150–262	150–262	Dropped	

PRICES

Prices have remained unchanged throughout the year as the result of price freezing:

TABLE 1.—*Oil and Gas Production in Michigan during* 1943

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
1	Adams, *Arenac*	1937	(960) 1,100	3,580,287	985,050		0	0	83	4	4
2	Akron-Wisner, *Tuscola*	1936	(300) 520	171,171	36,951		0	0	17	0	0
3	Austin (gas), *Mecosta*	1935	(1,800) 2,200	0	0		5,759	0	29	0	0
4	Bangor, *Van Buren*	1939	(160) 250	463,335	88,635		0	0	25	4	4
5	Bangor (North), *Van Buren*	1942	400	151,284	144,768		0	0	20	17	1
6	Beaverton, North, *Gladwin*	1935	(200) 360	669,010	18,615		0	0	28	0	0
7	South, *Gladwin*	1935	(460) 520	459,174	105,415		0	0	23	2	0
8	Bentley, *Gladwin*	1937	(840) 920	819,953	96,415		0	0	47	6	0
9	Birch Run, *Saginaw*	1934	300	206,487	7,394		0	0	28	0	0
10	Bloomingdale, *Van Buren*	1938	(2,000) 3,000	5,868,386	169,427		0	0	244	1	2
11	Breedsville, *Van Buren*	1943	140	60,273	60,273		0	0	9	9	0
12	Broomfield, *Isabella*	1930	(3,200) 4,100	0	0		7,988	526	62	0	3
13	Buckeye, North, *Gladwin*	1936	(1,760) 2,900	15,050,267	349,541		0	0	266	2	15
14	South, *Gladwin*	1936	(1,480) 2,500	3,880,007	88,408		0	0	188	0	4
15	Cedar, *Osceola*	1943	360	159,510	159,510		0	0	9	9	0
16	Clare (gas), *Clare*	1929	(240) 400	0	0		713	0	9	0	0
17	Clare City, *Clare*	1938	(80) 660	25,352	4,076		0	0	2	0	0
18	Clare City (gas), *Clare*	1938	600	0	0		1,271	125	7	0	0
19	Clayton (oil), *Arenac, Ogemaw*	1936	(1,100) 1,300	3,832,109	179,619		0	0	59	0	0
20	Clayton (gas), *Arenac*	1936	(1,280) 1,440	0	0		3,908	572	31	0	2
21	Columbia, *Van Buren*	1938	(800) 1,230	2,029,727	66,094		0	0	104	1	2
22	Crystal (oil), *Montcalm*	1935	(200) 2,180	7,260,166	48,693		0	0	235	0	0
23	Crystal (gas), *Montcalm*	1935	240	0	0		488	68	6	0	0
24	Deerfield, *Monroe*	1935	(200) 260	356,023	49,977		0	0	31	0	1
25	Diamond Springs, *Allegan*	1938	(240) 560	786,702	33,957		0	0	55	0	0
26	Dorr, *Allegan*	1938	(340) 480	294,907	14,089		0	0	27	1	1
27	Edmore, *Montcalm*	1933	(150) 160	441,779	9,158		0	0	13	0	1
28	Edenville, *Midland*	1938	(280) 400	1,173,726	34,843		0	0	35	0	3
29	Evart (oil), *Osceola*	1942	1,120	1,219,939	1,021,747		0	0	28	15	0
30	Evart (gas), *Osceola*	1941	3,520	0	0		302	272	21	4	0
31	Fork, *Mecosta*	1942	1,760	851,228	798,296		0	0	36	33	0
32	Freeman (gas), *Clare*	1938	(1,760) 2,080	0	0		1,914	582	16	0	2
33	Goodwell, *Newaygo*	1943	1,000	281,243	281,243		0	0	18	18	0
34	Gratiot, *Gratiot*	1927	(0) 400	228	0		0	0	3	0	0
35	Hart, *Oceana*	1932	(0) 180	116,275	0		0	0	17	0	0
36	Headquarters, *Clare-Roscommon*	1941	(1,540) 1,600	4,607,877	1,972,942		0	0	43	2	1

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg. End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
1	10*x*	48*x*	0	*x*	*x*	0	37 34.3	*x* *x*	Traverse, Dev Dundee, Dev	Lime Dol. Ls	*x* *x*	2,031 2,841	15 16	A A	Sylvania	4,950
2	0	10	0	*x*	*x*	0	43.2 42.6	1.56 *x*	Dundee, Dev Detroit River, Dev	Lime Dol. Ls	*x* *x*	2,840 3,371	5 13	A A	Sylvania	3,978
3	0	*x*	11	512	503	0	0	0	Stray-Marshall, Mis	Sand	*x*	1,390	10	A	Detroit River	4,042
4	0	15	0	*x*	*x*	0	28.5	*x*	Traverse, Dev	Lime	*x*	1,002	2	A	Traverse	1,248
5	0	19	0	*x*	*x*	0	*x*	*x*	Traverse, Dev	Lime	*x*	1,015	1	A	Traverse	1,060
6	0	13	0	*x*	*x*	0	41.3	0.16	Dundee, Dev	Lime	*x*	3,880	12	A	Dundee	4,029
7	0	22	0	*x*	*x*	0	41.3	0.16	Dundee, Dev	Lime	*x*	3,880	12	A	L. Detroit River	4,977
8	0	43	0	*x*	*x*	0	41.4	*x*	Dundee, Dev	Lime	*x*	3,500	25	A	Sylvania	5,115
9	0	25	0	*x*	*x*	0	42.4	0.25	Berea, Mis	Sand	*x*	1,529	13	A	Dundee	2,760
10	0	94	0	*x*	*x*	0	41.2	0.51	Traverse, Dev	Lime	*x*	1,216 1,277	2.5 1.5	A	Detroit River	1,904
11	0	9	0	*x*	*x*	0	*x*	*x*	Traverse, Dev	Lime	*x*	1,077	1.5	A	Detroit River	1,300
12	0	0	38	580	*x*	0	0	0	Stray-Marshall, Mis	Sand	*x*	1,300	5	A	Detroit River	4,031
13	0	162	0	*x*	*x*	0	39.0	0.25	Dundee, Dev	Lime	*x*	3,621	11	A	Detroit River	4,696
14	0	78	0	*x*	*x*	0	39.0	0.25	Dundee, Dev	Lime	*x*	3,574	11	A	Detroit River	4,330
15	0	9*x*	0	*x*	*x*	0	38.5	*x*	Dundee, Dev	Dol. Ls	*x*	3,815	2	A	Detroit River	3,972
16	0	0	6	*x*	*x*	0	0	0	Stray-Marshall, Mis	Sand	*x*	1,408	5	A	Detroit River	4,055
17	0	2	0	*x*	*x*	0	30.5	0.40	Stray-Marshall, Mis	Sand	*x*	1,283	2	A	Dundee	3,865
18	0	0	7	605	*x*	0	0	0	Stray-Marshall, Mis	Sand	*x*	1,283	6.5	A		
19	0	44	0	*x*	*x*	0	34.3	*x*	Dundee, Dev	Lime	*x*	2,534	12	A	Sylvania	4,163
20	0	0	26	620	*x*	0	0	0	Berea, Mis	Dol. sd.	*x*	1,166	12	A		
21	0	52	0	*x*	*x*	0	39.2	0.57	Traverse, Dev	Lime	*x*	1,190	2.5	A	Detroit River	1,904
22	0	19	0	*x*	*x*	0	45.2	*x*	Dundee, Dev	Dol. Ls	*x*	3,191	4	A	Detroit River	3,520
23	0	0	6	*x*	*x*	0	0	0	Stray-Marshall, Mis	Sand	*x*	1,016	4	A		
24	0	22	0	*x*	*x*	0	40.0	*x*	Trenton, Ord	Dol. Ls	*x*	2,102	9	MF	St. Peter	3,088
25	0	23	0	*x*	*x*	0	*x*	*x*	Traverse, Dev	Lime	*x*	1,466	3.5	A	Traverse	1,571
26	0	18	0	*x*	*x*	0	41.4	0.44	Traverse, Dev	Lime	*x*	1,596	4	A	Niagaran	3,319
27	0	5	0	*x*	*x*	0	43.2	0.11	Traverse, Dev	Lime	*x*	3,108	4	A	Dundee	3,700
28	0	23	0	*x*	*x*	0	41.3	*x*	Dundee, Dev	Lime	*x*	3,788	8	A	Dundee	4,015
29	0	28	0	1,456	1,412	0	46.0	*x*	Dundee, Dev	Lime	*x*	3,757	5.7	A	Detroit River	4,457
30	0	0	17	578	*x*	0	0	0	Stray-Marshall, Mis	Sand	*x*	1,425	9.7	A		
31	0	36	0	1,508	1,429	0	*x*	*x*	Dundee, Dev	Dol. Ls	*x*	3,832	2.5	A	Dundee	4,013
32	0	0	13	607	482	0	0	0	Stray-Marshall, Mis	Sand	*x*	1,486	12	A	Detroit River	3,957
33	6	12	0	1,020	*x*	0	43.0	*x*	Traverse, Dev	Lime	*x*	2,784	2	A	Detroit River	3,562
34	0	0	0	*x*	*x*	0	*x*	*x*	Parma, Pen	Sand	*x*	500	10	A	Dundee	3,100
35	0	0	0	*x*	*x*	0	34.0	*x*	Traverse, Dev	Lime	*x*	1,880	4	A	Dundee	2,436
36	7*x*	35*x*	0	1,509	622	0 0	40.6 48.9	0.16 1.42	Traverse, Dev Detroit River, Dev	Lime Dol.	*x* *x*	3,285 3,838	5 13	A A	Sylvania	6,029

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
37	Home, *Montcalm*	1938	(2,440) 5,160	0	0		4,724	1,080	25	0	5
38	Kawkawlin, *Bay*	1938	4,320	1,403,728	685,117		0	0	110	32	0
39	Leaton, *Isabella*	1929	(1,000) 2,140	3,099,872	102,074		0	0	81	0	3
40	Leaton (gas), *Isabella*	1929	(0) 480	0	0		186	0	12	0	1
41	Lincoln, *Clare*	1938	(2,400) 2,720	0	0		3,626	1,172	15	0	0
42	Marion-Winterfield (gas), *Osceola-Clare*	1940	(9,120) 10,400	0	0		6,254	3,010	81	1	2
43	Marion-Winterfield (oil), *Clare*	1940	(860) 1,320	3,053,017	684,349		0	0	42	2	0
44	Monterey, *Allegan*	1938	(190) 300	396,695	19,497		0	0	28	0	0
45	Mt. Pleasant, *Midland-Isabella*	1928	(1,790) 8,050	22,189,902	303,827		0	0	447	0	2
46	Muskegon, *Muskegon*	1927	(250) 2,700	6,739,996	26,140		0	0	412	0	1
47	Muskrat Lake, *Van Buren*	1941	(500) 1,050	259,005	45,363		0	0	54	2	13
48	New Haven, *Gratiot*	1935	(1,800) 2,400	0	0		5,973	1,470	53	0	3
49	Norwich (East), *Missaukee*	1942	480	28,528	25,326		0	0	7	4	0
50	Overisel, *Allegan*	1938	(1,920) 2,080	2,174,769	126,660		0	0	155	0	3
51	Porter Yost, *Midland*	1931	(6,440) 8,440	40,435,088	1,019,471		0	0	536	0	3
52	Prosper, *Missaukee*	1942	520	398,074	395,598		0	0	13	12	0
53	Ravenna, *Muskegon*	1936	(3,000) 3,840	0	0		1,434	157	29	0	2
54	Reed City (oil), *Osceola, Lake*	1941	(5,000) 5,280	19,634,372	7,776,082		0	0	186	4	2
55	Reed City (gas), *Osceola, Lake*	1940	4,320	0	0		5,144	1,981	29	0	0
56	Richfield, *Roscommon*	1941	(480) 520	149,872	77,939		0	0	12	1	0
57	Riverside (gas), *Missaukee*	1940	3,200	0	0		939	817	17	4	0
58	Rose Lake, *Osceola*	1943	800	74,604	74,603		0	0	8	8	0
59	Saginaw, *Saginaw*	1925	(450) 1,800	1,414,255	19,742		0	0	282	0	12
60	Salem, *Allegan*	1937	(1,950) 2,500	3,048,754	107,353		0	0	205	0	4
61	Salem (New), *Allegan*	1938	(880) 1,100	3,519,764	220,346		0	0	104	0	12
62	Sauble, *Lake*	1942	(160) 200	49,274	22,588		0	0	5	0	1
63	Sherman, *Isabella*	1936	(970) 1,220	4,186,304	177,939		0	0	96	0	6
64	Six Lakes, *Mecosta, Montcalm*	1934	(8,080) 10,280	0	0		35,526	4,897	247	0	15
65	South Tallmadge, *Ottawa*	1939	(970) 1,000	359,789	62,575		0	0	62	1	0
66	Temple, *Clare*	1938	(1,890) 2,710	13,544,499	517,153		0	0	166	0	8
67	Trowbridge, *Allegan*	1941	(940) 1,280	169,721	30,729		0	0	38	4	8
68	Vernon (oil), *Isabella*	1930	(570) 1,100	4,468,690	75,241		0	0	73	0	1
69	Vernon (gas), *Isabella*	1930	(240) 920	0	0		1,431	15	11	0	1

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil		Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift														
37	0	0	17	515	x	0	0	0	Stray-Marshall, Mis	Sand	x	1,390	7.5	A	Dundee	3,565
38	0	109	0	x	x	0	34 9	0.37	Dundee, Dev	Lime	x	2,846	35.8	A	St. Peter	10,447
39	0	43	0	x	x	0	43	0.16	Dundee, Dev	Lime	x	3,634	7.5	A	Dundee	3,594
40	0	0	0	607	x	0	0	0	Stray-Marshall, Mis	Sand	x	1,239	4	A		
41	0	0	13	607	465	0	0	0	Stray-Marshall, Mis	Sand	x	1,526	10	A	Detroit River	4,285
42	0	0	57	x	x	0	0	0	Stray-Marshall, Mis	Sand	x	1,392	9	A	L. Detroit River	5,100
43	8x	32x	0	1,510	1,472	0	44 38 41.5	0.5 x x	Traverse Dundee Detroit River } Dev	Lime Lime Dol. Sd	x	3,140 3,743 5,014	5 3 6	A	L. Detroit River	5,100
44	0	17	0	x	x	0	37.6	x	Traverse, Dev	Lime	x	1,638	3	A	Traverse	1,808
45	0	179	0	x	x	0	41.5	0.13	Dundee, Dev	Lime	x	3,536	14.6	A	Sylvania	4,821
46	0	25	0	x	x	0 0	37.4 x	0.56 x	Traverse, Dev Dundee, Dev	Lime Lime	x x	1,682 2,050	3.5 10	A A	St. Peter	4,754
47	0	33	0	x	x	0	x	x	Traverse, Dev	Lime	x	1,283	1.5	A	Traverse	1,332
48	0	0	45	448		0	0	0	Stray-Marshall, Mis	Sand	x	915	5	A	Dundee	3,536
49	0	7	0	x	x	0	x	x	Dundee, Dev Detroit River, Dev	Lime Dol. Sd	x x	3,082 4,389	5 4.2	A A	Detroit River	4,524
50	0	93	0	x	363	0	39.4	0 54	Traverse, Dev	Lime	x	1,471	3	A	Detroit River	1,972
51	0	323	0	x	x	0	41.3	0.26	Dundee, Dev	Lime	x	3,422	12	A	Sylvania	4,733
52	0	13x	0	1,402	800	0	x	x	Dundee, Dev	Dol. Ls	x	3,832	4	A	Dundee	3,947
53	0	0	24	720		0	0	0	Berea, Mis	Lime	x	1,212	10	A	Dundee	2,306
54	78x	106x	0	1,414	785	0	45	0 6	Traverse, Dev Dundee, Dev Detroit River, Dev	Lime Lime Dol.	x x x	2,935 3,492 3,540	5 3 7	A A A	L. Detroit River	4,333
55	0	0	29	438	310	0	0	0	Stray-Marshall, Mis	Sand	x	1,210	5	A		
56	0	12	0	x	x	0	35	x	Detroit River, Dev	Dol.	x	4,191	8	A	Sylvania	4,440
57	0	0	17	x	x	0	0	0	Stray-Marshall, Mis	Sand	x	1,331	15.7	A	Dundee	3,945
58	0	8x	0	1,113	x	0	37.5	x	Traverse, Dev	Lime	x	3,125	5	A	Detroit River	3,990
59	0	43	0	x	x	0	44.3	0 24	Berea, Mis	Dol. Sd.	x	1,820	16	A	Sylvania-Bass Island	3,985
60	0	153	0	x	x	0	41 0	0.6	Traverse, Dev	Lime	x	1,587	8	A	Trenton	3,792
61	0	72	0	x	388	0	41 8	0 56	Traverse, Dev	Lime	x	1,621	6	A	Detroit River	1,968
62	0	4	0	x	x	0	35 5	x	Traverse, Dev	Lime	x	2,134	1.5	A	Sylvania	3,765
63	0	52	0	x	x	0	47.8	x	Dundee, Dev	Dol. Ls	x	3,648	4	A	Detroit River	4,031
64	0	0	172	516	195	0	0	0	Stray-Marshall, Mis	Sand	x	1,275	16	A	Detroit River	3,790
65	0	54	0	x	x	0	42.0	x	Traverse, Dev	Lime	x	1,820	7.5	A	Traverse	2,030
66	0	107	0	1,546	1,518	0	43.8	0.37	Dundee, Dev	Dol.	x	3,895	4 5	A	Sylvania	5,462
67	0	28	0	x	x	0			Traverse, Dev	Lime	x	1,350	2	A	Detroit River	1,645
68	0	32	0	x	x	0	44.1	0.3	Dundee, Dev	Dol. Ls	x	3,741	3	A	Dundee	3,899
69	0	0.	5	575	x	0	0	0	Stray-Marshall, Mis	Sand	x	1,300	2.2	A		

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c] To End of 1943	Oil Production Total, Bbl.[c] During 1943	Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e] To End of 1943	Gas Production, Millions Cu. Ft.[e] During 1943	Number of Oil and/or Gas Wells[f] Completed to End of 1943	1943 Completed	1943 Abandoned
70	Walker, *Kent*	1938	(4,550) 5,700	9,461,362	449,284		*x*	*x*	494	1	33
71	West Branch, *Ogemaw*	1933	(4,500) 5,000	5,187,573	297,817		0	0	258	0	0
72	West Hopkins, *Allegan*	1941	(440) 480	355,566	45,725		0	0	31	0	3
73	Winfield (gas), *Montcalm*	1938	2,660	0	0		2,601	622	16	0	0
74	Winfield (oil), *Montcalm*	1938	80	51,452	4,014		0	0	5	0	0
75	Wise (oil), *Isabella*	1938	(1,120) 1,320	1,906,054	176,971		0	0	62	0	0
76	Wise (gas), *Isabella*	1938	(900) 960	0	0		724	157	6	0	0
77	Woodville, *Newaygo*	1943	280	67,256	67,256		0	0	7	7	0
78	Wyoming Park, *Kent*	1939	(400) 450	112,128	9,898		0	0	21	0	1
79	Zeeland, South, *Ottawa*	1942	(380) 400	120,248	84,576		0	0	15	8	1
80	Miscellaneous			1,134,987	146,023		11	2	269	64	22
81	Totals		153,100	204,011,622	20,642,412		90,916	17,525	6,699	283	214

Line Number	Wells Producing[g] Dec. 1943 Oil Flowing	Wells Producing[g] Dec. 1943 Oil Artificial Lift	Wells Producing[g] Dec. 1943 Gas	Reservoir Pressure, Lb. per Sq. In. Initial	Reservoir Pressure, Lb. per Sq. In. Avg./End 1943	Secondary Recovery[h]	Character of Oil[i] Gravity A.P.I. at 60°F.	Character of Oil[i] Sulphur, Per Cent	Producing Formation Name and Age[j]	Producing Formation Character[k]	Producing Formation Porosity, Per Cent[l]	Producing Formation Depth to Top of Producing Zone, Ft.[m]	Producing Formation Productive Thickness, Avg. Ft.,[n] Net	Producing Formation Structure[o]	Deepest Zone Tested[p] to End of 1943 Name	Deepest Zone Tested[p] to End of 1943 Depth of Hole, Ft.
70	0	121	0	792	*x*	0	42.1	0.4	Traverse, Dev	Lime	*x*	1,827	6	A	St. Peter	5,222
71	0	233	0	*x*	*x*	0 0	33.4 *x*	0.35 *x*	Traverse, Dev Dundee, Dev	Lime Lime	*x* *x*	1,880 2,622	5 20	A A	Salina	5,405
72	0	28	0	*x*	*x*	0	41.5	*x*	Traverse, Dev	Lime	*x*	1,587	2	A	Traverse	1,633
73	0	0	16	446	345	0	0	0	Stray-Marshall, Mis	Sand	*x*	1,124	8	A	Detroit River	3,314
74	0	4	0	*x*	*x*	0	*x*	*x*	Detroit River, Dev	Dol.	*x*	3,355	1	A	Detroit River	3,374
75	0	60	0	*x*	*x*	0	47.0	*x*	Dundee, Dev	Lime	*x*	3,702	10.5	A	Dundee	3,854
76	0	0	6	606	*x*	0	0	0	Stray-Marshall, Mis	Sand	*x*	1,249	5	A	Dundee	3,854
77	0	7	0	*x*	*x*	0	*x*	*x*	Traverse, Dev	Lime	*x*	2,822	4.5	A	Detroit River	3,534
78	0	12	0	*x*	*x*	0	41.5	*x*	Traverse, Dev	Lime	*x*	1,191	6	A	Detroit River	2,255
79	0	14	0	*x*	*x*	0	31	*x*	Traverse, Dev	Lime	*x*	1,494	2.1	A	Detroit River	2,053
80	0	74	77													
81	114	3,073	602													

TABLE 2.—*Summary of Drilling Operations in Michigan during 1943*

Important Wildcats Drilled in 1943
Surface Formation, Pleistocene

	County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Sec.	Tp.	Rge.				Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	Allegan	11	4 N	15 W	1,541	Traverse	J. W. Lang & Mich. Dev. Petr.	4	0	Discovery of Traverse production in Fillmore township
2	Antrim	14	31 N	8 W	6,150	St. Peter	Ohio Oil Co.	0	0	Deepest test in Antrim County. Penetrated St. Peter sandstone
3	Arenac	3	19 N	6 E	4,315	Detroit River	W. L. McClanahan	Filled up 250 ft.	0	Impressive showing of oil in Detroit River formation in Au Gres township
4	Arenac	33	20 N	3 E	2,982	Dundee	Don Rayburn	0	0	Important showing of oil in Dundee and gas in Berea in Moffatt township
5	Clare	25	20 N	3 W	4,851	Detroit River	Freeman Oil Co.	70	0	Discovered commercial production in Detroit River formation in Southern Franklin township
6	Clare	2	20 N	6 W	1,323	Stray-Marshall	Taggart Bros. Inc.	0	11.6	Discovery well of Cranberry Lake gas field
7	Clare	1	20 N	6 W	3,840	Dundee	Leonard & Rowmor Corp.	Filled up 3,000 ft.	0	Important showing of oil in Dundee in Cranberry Lake field
8	Clare	6	18 N	4 W	5,633	Detroit River	Pure Oil Co.	0	0	Deep test. Penetrated Sylvania formation
9	Clare	33	19 N	6 W	5,462	Detroit River	Pure Oil Co.	0	0	Deep test. Penetrated lower Detroit River formation in Temple oil field
10	Gladwin	19	17 N	2 W	3,911	Dundee	Sun Oil Co.	Filled up 1000 ft.	0	Discovery of commercial production in West Beaverton township
11	Gratiot	36	11 N	3 W	908	Stray-Marshall	C. E. Weller & T. F. Caldwell	0	16.6	Discovery of commercial gas in Arcada township
12	Ingham	14	3 N	1 E	6,599	St. Peter	Wm. H. Colvin & Associates	0	0	Deep test. Penetrated St. Peter sandstone
13	Leelanau	5	29 N	12 W	4,307	Niagaran	F. M. Copeland & P. M. Barton	0	0	Deep test. Penetrated top of Niagaran
14	Newaygo	29	15 N	11 W	3,534	Detroit River	Ohio Oil Co.	10	0	Discovery well of Woodville field, Newaygo County
15	Newaygo	8	14 N	11 W	2,743	Traverse	Pure Oil Co.	1,134	0	Discovery well of Goodwell field, Newaygo County
16	Ogemaw	33	24 N	2 E	5,367	Detroit River	A. Weber & Associates	10	0	Discovery of commercial production in Detroit River formation on Rose City structure
17	Osceola	31	19 N	9 W	3,990	Detroit River	Union Prod. & Drill Co.	Filled up 1,400 ft.	0	Discovery well of Rose Lake field
18	Osceola	28	18 N	9 W	3,834	Dundee	Ohio Oil Co.	732 est.	0	Discovery well of Cedar oil field
19	Osceola	29	18 N	8 W	5,315	Sylvania	Sun Oil Co.	0	0	Deep test. Penetrated Sylvania sandstone
20	Van Buren	24	1 S	16 W	1,071	Traverse	Clock Oil Co.	50	0	Discovery well of Breedsville field
21	Wayne	18	4 S	9 E	2,654	Trenton	Voorhees Drill. Co.	10 bbl. AA	0	Discovery well of New Boston field

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1943	45	65
Number of oil wells completed during 1943	233	4
Number of gas wells completed during 1943	44	2
Number of dry holes completed during 1943	123	223

Midland-grade crude, $1.44; Sherman-grade crude, $1.39.

ACKNOWLEDGMENTS

Mr. Carl C. Addison, Division Geologist of The Pure Oil Co. at Saginaw, Mich., and Mr. D. C. Shackelford, Chief Scout of that company, assisted in the preparation of this report. Miss Lou Williams and Mr. C. K. Clark, of The Pure Oil Co., gave particular attention to the tabulated data. As in the past, the State Geological Survey of Michigan has furnished information on oil and gas production.

Oil and Gas Development in Mississippi during 1943

By H. M. Morse*

This report covers the period from Jan. 1, 1943 to Dec. 31, 1943.

During the year, 112 wells were drilled in Mississippi, as follows: wildcats drilled and abandoned, 54; wildcats producing oil, 4; oil wells drilled in oil fields, 26; oil wells drilled in fields, dry and abandoned, 10; sulphur-test wells drilled, 14; salt-water-disposal wells, 3; core tests, 1.

PROSPECTING

Geophysical work in Mississippi during 1943 amounted to 1127 crew weeks, divided as follows: reflection seismograph, 809 weeks; gravity meter, 285; magnotometer, 30; torsion balance, 3.

A considerable amount of core drilling was done over a large part of the state. The complete data on this activity are not available at the present time.

SALT DOMES

To date, the following salt domes have been discovered in Mississippi: Midway, Edwards, Glass, Newman, Tatum, Oakvale, Kings, Halifax, D'Lo, Hazlehurst, Byrd, Leedo, Prentiss, Carson, Moselle, Monticello, Ruth, Keno, Taylorsville.

NEW OIL FIELDS

Lincoln County.—On March 10, 1943, the California Company completed its Smith No. 1 in sec. 4, T. 7 N., R. 7 E., Lincoln County, as an oil well and produced 29 bbl. of 25° gravity oil in 24 hr. through a ¼-in. choke. Two outpost wells have been drilled in this area by the California Company, and both have been abandoned as dry holes.

Madison County.—Love Petroleum Co. completed its J. R. Anderson No. 2, sec. 2, T. 8 N., R. 1 W., Madison County, on Sept. 7, 1943. This well produced 135 bbl. of approximately 30° gravity oil in 24 hr. through a ¼-in. choke. The production comes from a sand or porosity in the upper part of the Chalk formation of the Cretaceous age.

Adams County.—The California Company drilled its National Gasoline Co. of Louisiana No. 1 in sec. 52, T. 7 N., R. 1 W., to a total depth of 10,383 ft., and at 10,280 ft. it perforated and obtained gas and a condensate. The well had several showings in the Wilcox of the Eocene age. Several of these showings were tested and the well finally was completed at 5888 ft. on Oct. 6, 1943, producing 44° gravity oil in the second sand in this formation. No other wells were completed in this field during the year. However, a number of wells are contemplated in the near future, and locations have been staked by the California Company. The Oklahoma Pipe Line Co. will market the oil through its pipe-line facilities.

Wayne County.—The Gulf Refining Co. drilled Davis No. 1 in sec. 2, T. 9 N., R. 9 W. in Wayne County. After several stem tests 5½-in. casing was set at 6850 ft. and production was obtained in the so-called Massive Sand of the Lower Tuscaloosa. The well produced 359 bbl. of oil in 24 hr., and it was completed on Oct. 4, 1943. Other locations have been staked in this area and probably will be drilled in 1944 by

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* Supervisor State Oil and Gas Board, Jackson, Mississippi.

the Gulf Refining Co., the Humble Oil and Refining Co., and other lease holders.

WILDCATS

Two very interesting wildcats of considerable importance were drilled in the eastern part of the state.

One of these is the Hilma Wall No. 1 in sec. 28, T. 5 N., R. 13 E., Newton County, which was drilled by the Sun Oil Co. to a total depth of 10,117 ft. It was completed as a dry hole in Jurassic formations on Aug. 23, 1943. This well encountered the Smackover lime at 8300 feet.

The other well is the Southern Natural Gas Company's J. W. Smith No. 1 in sec. 1, T. 9 N., R. 11 E., Neshoba County, approximately 30 miles north of the well in Newton County. This well was drilled to a total depth of 6875 ft. and was completed as a dry hole on Nov. 19, 1943. This well also reached the Jurassic formations. It encountered the Smackover lime at 6300 ft. This well showed the Smackover lime some 2000 ft. higher than the Newton County well.

TABLE 1.—*Oil and Gas Production in Mississippi*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
									1943	
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned
1	Brookhaven, *Lincoln*	1943	40	16,711	16,711			1	1	0
2	Cary, *Sharkey*	1941	160	30,490	19,987			5	1	0
3	Cranfield, *Adams*	1943	40	12,891	12,891			1	1	0
4	Eucutta, *Wayne*	1943	80	1,663	1,663			1	1	0
5	Flora, *Madison*	1943	80	4,714	4,714			2	2	0
6	Tinsley, *Yazoo*	1939	9,840	65,046,178	17,264,156			360	1	7
7	Vaughan-Pickens, *Madison and Yazoo*	1940	1,400	2,392,483	1,458,651			34	23	0
8	Jackson, *Rankin and Hinds*	1930				114,771,014	1,349,936	218	0	4

Line Number	Wells Producing[g] Dec. 1943			Character of Oil[i]	Producing Formation			Deepest Zone Tested[p] to End of 1943	
	Oil		Gas	Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Depth to Top of Producing Zone, Ft.[m]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift							
1	0	1		25	Marine Tuscaloosa	Sand	10,288	L. Cretaceous	12,229
2	1	0		24.8	Selma Chalk, Cre		3,270	Cretaceous	3,775
3	1	0		44	Wilcox-Eocene		5,888	M. Tuscaloosa	10,383
4	0	1		27	Tuscaloosa	Sand		M. Tuscaloosa	7,100
5	0	2		30	Selma Chalk of CreU		4,360	Chalk	4,367
6	5	324		31.6 to 49.6	Selma C., Eutaw, Tuscaloosa		4,378	Tuscaloosa	6,540
7	8	25		39.9	Eutaw of Cre	Sand	4,830	Tuscaloosa	5,658
8			19		Selma, Cre	Gas	2,420	L. Cretaceous	5,529

[b] Footnotes to column heads and explanation of symbols are given on page 270.

In the northwestern part of Lauderdale County, the Magnolia Petroleum Co. drilled the Culpepper No. 1 in 1941, in sec. 4, T. 8 N., R. 14 E. This well went from the Upper Cretaceous formations into the Paleozoic rocks; thus a few miles to the west Lower Cretaceous and Jurassic formations of considerable thickness were

TABLE 2.—*Summary of Drilling Operations in Mississippi*

SURFACE FORMATION, RECENT

Important Wildcats Drilled in 1943

	County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Pressure, Lb. per Sq. In.		Remarks
		Sec.	Tp.	Rge.				Casing	Tubing	
1	Adams	52	7 N	1 W	10,383	L. Cretaceous	California Co.	5½ in., 10,383	5,880	Oil
2	Adams	1	6 N	4 W	11,102	L. Cretaceous	Pure Oil Co.	5½ in., 11,100		Abandoned
3	Attala	4	16 N	6 E	5,735	Paleozoic	Hunt Oil Co.			D. and A.[1]
4	Bolivar	4	23 N	5 W	5,057	Paleozoic	Hunt Oil Co.			D. and A.
5	Claiborne	66	11 N	2 E	9,903	L. Cretaceous	Amerada Petr. Co.			D. and A.
6	Clarke	24	4 N	16 E	4,535	L. Tuscaloosa	H. W. Elliott			D. and A.
7	Clarke	29	3 N	17 E	5,415	L. Cretaceous	C. L. Higgason			D. and A.
8	Clarke	10	2 N	16 E	3,714	Eutaw	A. B. Irion et al.	4 in., 3,700		Abandoned
9	Clarke	14	2 N	16 E	3,719	Eutaw	A. B. Irion et al.	4 in., 3,700		Abandoned
10	Copiah	16	11 N	5 E	10,502	L. Cretaceous	Carter Oil Co.			D. and A.
11	Greene	16	3 N	7 W	2,135	Salt	Gulf Refining Co.			D. and A.
12	Greene	33	5 N	8 W	12,328	L. Cretaceous	Humble Oil & Ref. Co.			D. and A.
13	Hinds	36	8 N	3 W	6,872	Eutaw	W. J. Goldston			D. and A.
14	Hinds	14	5 N	2 W	7,560	L. Tuscaloosa	Plains Prod. Co.			D. and A.
15	Hinds	29	6 N	3 W	9,002	L. Cretaceous	Pure Oil Co.			D. and A.
16	Humphreys	24	14 N	4 W	5,500	L. Cretaceous	Gregg-Tex Gasoline Co.			D. and A.
17	Humphreys	16	16 N	3 W	6,161	L. Cretaceous	Roeser & Pendleton, Inc.			D. and A.
18	Issaquena	26	13 N	8 W	4,000	L. Cretaceous	Hunt Oil Co.			D. and A.
19	Issaquena	8	13 N	8 W	4,010	L. Cretaceous	Hunt Oil Co.			D. and A.
20	Issaquena	24	11 N	8 W	3,544	L. Cretaceous	C. H. Lathrop			D. and A.
21	Issaquena	24	11 N	9 W	3,411	L. Cretaceous	C. H. Lathrop			D. and A.
22	Jackson	20	5 S	8 W	11,378	L. Cretaceous	Humble Oil & Ref. Co.			D. and A.
23	Jefferson	19	8 N	4 E	2,070	Salt	Gulf Refining Co.			D. and A.
24	Jones	31	7 N	13 W	2,294	Cap Rock	Gulf Refining Co.			D. and A.
25	Kemper	36	10 N	17 E	2,808	L. Cretaceous	Wanete Oil Co.			D. and A.
26	Lawrence	28	5 N	11 E	11.446	L. Cretaceous	William Helis et al.			D. and A.
27	Lincoln	4	7 N	7 E	12,229	L. Cretaceous	California Co.	5½ in., 10,000		Abandoned
28	Lincoln	4	7 N	7 E	12,843	L. Cretaceous	California Co.			D. and A.
29	Madison	30	11 N	4 E	6,748	L. Cretaceous	The Carter Oil Co.			D. and A.
30	Madison	10	9 N	1 E	7,015	L. Cretaceous	J. P. Evans & Dinkins			D. and A.
31	Madison	19	9 N	1 E	9,007	L. Cretaceous	Love Petr. Co.			D. and A.
32	Madison	2	8 N	1 W	4,367	Selma	Love Petr. Co.	5½ in., 4,000		
33	Madison	11	9 N	5 E	6,412	L. Tuscaloosa	Love Petr. Co.			D. and A
34	Madison	1	11 N	3 E	5.046	Eutaw	F. H. Shortridge et al.			D. and A.
35	Madison	9	10 N	4 E	6,510	Tuscaloosa	Tip Ray et al.			D. and A.
36	Marion	20	3 N	17 W	1,520	Cap Rock	Gulf Refining Co.			D. and A.
37	Neshoba	1	9 N	11 E	6,875	Jurassic	Sou. Natural Gas Co.			D. and A.
38	Newton	28	5 N	13 E	10,117	Jurassic	Sun Oil Co.			D. and A.
39	Pontotoc	3	10 S	3 E	2,234	Paleozoic	S. A. Guiberson, Jr.			D. and A.
40	Rankin	21	8 N	5 E	6,132	Tuscaloosa	Love Petroleum Co.			D. and A.
41	Sharkey	19	13 N	5 W	5,051	L. Cretaceous	The Texas Co.			D. and A.
42	Simpson	17	1 N	4 E	9,578	L. Cretaceous	Carter Oil Co.			D. and A.
43	Simpson	8	2 N	4 E	9,500	L. Cretaceous	Gulf Refining Co.			D. and A.
44	Stone	30	2 S	12 W	8,513	L. Cretaceous	H. I. Morgan			D. and A.
45	Smith	5	10 N	13 W	2,020	Cap Rock	Gulf Refining Co.			D. and A.
46	Stone	10	4 S	10 W	8,352	L. Tuscaloosa	R. W. Norton, Jr.			D. and A.
47	Washington	26	18 N	6 W	6,428	L. Cretaceous	Grubb & Hawkins			D. and A.
48	Washington	20	19 N	8 W	6,105	L. Cretaceous	Roeser & Pendleton, Inc.			D. and A.
49	Wayne	2	9 N	9 W	7,100	L. Cretaceous	Gulf Refining Co.	5½ in., 7,100		
50	Wayne	2	6 N	7 W	8,570	L. Cretaceous	Humble Oil & Ref. Co.			D. and A.
51	Yazoo	8	10 N	2 E	6,011	Eutaw	H. I. Morgan			D. and A.
52	Yazoo	6	13 N	2 W	6,271	Tuscaloosa	N. Ordnance Co.			D. and A.
53	Yazoo	18	12 N	3 W	6,385	Tuscaloosa	N. Ordnance Co.			D. and A.
54	Yazoo	8	11 N	5 W	5,511	L. Cretaceous	Nelson Brothers			D. and A.

[1] D. and A. indicates dry and abandoned.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1943	26	4
Number of oil wells completed during 1943	0	0
Number of gas wells completed during 1943	10	54
Number of dry holes completed during 1943		

encountered. A great deal of interest is being manifested in this area because of these conditions.

Oil Production

During 1943 the Tinsley oil field produced 17,264,156 bbl. of oil. The cumulated figure for this field in Yazoo County, from Sept. 11, 1939 to Jan. 1, 1944, is 65,046,178 bbl. of oil.

The Vaughan-Pickens field, now made up of the Vaughan-Pickens field and the Pickens-Sharpsburg field, produced 1,458,651 bbl. of oil in 1943. Its cumulated production since April 8, 1940 is 2,392,483 bbl. of oil. This field is in Yazoo and Madison Counties.

The Brookhaven field, Lincoln County, produced 16,711 bbl. of oil in 1943.

In Sharkey County, the Cary oil field produced 19,987 bbl. of oil in 1943. There is a cumulated production of 30,490 bbl. since Sept. 16, 1941.

The Cranfield field, Adams County, produced 12,891 bbl. of oil in 1943.

The Eucutta field, Wayne County, shows a production of 1663 bbl. for 1943.

The Flora oil field produced 4714 bbl. of oil.

In Adams County, sec. 1, T. 6 N., R. 4 W., the Pure Oil Co. drilled the J. M. McDowell No. 1 and produced 379 bbl. of net oil.

The total amount of oil produced in Mississippi in 1943 was 18,779,423 bbl. The total cumulated production was 67,505,509 barrels.

Development of Oil and Gas in Missouri in 1943

By Frank C. Greene*

Drilling in Missouri in 1943 continued at a lower rate than in 1942, only 28 wells being completed. Following the completion of the Cities Service Oil Company's No. 1 Jim Cook near Tarkio, in the northwest corner, NW. ¼ sec. 32, T. 65 N., R. 39, W., Atchison County, four dry holes were drilled by other parties, all a mile or more from the Cook well. Later the Cities Service Oil Co. completed No. 2 Cook for 60 bbl. Table 1 gives a summary of activities by counties.

The total footage drilled was 23,831½ ft., of which 12,802½ ft. was by cable tools and 11,029 by rotary. Four of the dry holes were drilled into Mississippian or older beds.

Table 1.—*Wells Drilled for Oil and Gas in Missouri in* 1943

County	Number of Oil Wells	Number of Gas Wells	Dry
Atchison	2		4
Bates			1
Caldwell			1
Cass			1
Clay			2
Clinton			5
Holt			1
Jackson		5	3
Platte			2
Worth			1
Totals	2	5	21

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* Geologist, Missouri Geological Survey, Rolla, Missouri.

Petroleum Development in Nebraska in 1943

By E. C. Reed*

Drilling operations in Nebraska during 1943 were reduced to approximately two thirds of the 1942 number. Twenty-seven wells were completed during 1943 and five wells were drilling at the close of the year. Eight of the completions, in proven fields, were producers. The operations were distributed throughout the state as follows: eleven in Richardson County, four each in Buffalo and Harlan Counties, three in Furnas County, and single operations in Antelope, Butler, Dakota, Dawes, Gage, Nemaha, Otoe, Pawnee, Scotts Bluff and Sherman Counties.

Table 1.—*Oil and Gas Production in Nebraska*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres^{b}	Oil Production Total, Bbl.^{c}		Number of Oil Wells^{f}		
				To End of 1943	During 1943	Completed to End of 1943	1943	
							Com-pleted	Aban-doned
1	Barada, *Richardson*	1941	480	614,600	206,000	15	0	0
2	Dawson, *Richardson*	1940	440	68,000	42,900	13	7	0
3	Falls City, *Richardson*	1939	1,080	3,347,000	425,900	57	1	1
4	Shubert, *Richardson*	1940	400	116,000	13,600	10	0	1
5	Total		2,400	4,145,600	688,400	95	8	2

Line Number	Wells Producing^{g} Dec. 1943	Character of Oil^{i}	Producing Formation					Deepest Zone Tested^{p} to End of 1943	
	Oil, Artificial Lift	Gravity A.P.I. at 60°F.	Name and Age^{j}	Character^{k}	Porosity, Per Cent^{l}	Depth to Top of Producing Zone, Ft.^{m}	Productive Thickness, Avg. Ft.,^{n} Net	Name	Depth of Hole, Ft.
1	15	29.6	Hunton, Dev	D	Cav	2,403	78	Viola	3,215
2	13	21.7	Hunton and Viola, Dev, Ord	D	Cav	2,192 2,897	29 4	Pre-Cambrian	3,424
3	56	31.5	Hunton, Dev	D	Cav	2,250	23	Arbuckle	3,372
4	9	31	Hunton, Dev	D	Cav	2,495	23	Hunton	2,638
5	93								

The principal feature of exploration drilling in the state during the year was the more extensive testing in the central Nebraska Basin region, principally in Buffalo and Harlan Counties, where

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* Nebraska Geological Survey, Lincoln, Nebraska.

TABLE 2.—*Summary of Drilling Operations in Nebraska*

Important Wildcats Drilled in 1943

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day	Remarks
		Sec.	Tp.	Rge.					Oil, U. S. Bbl.	
1	Antelope . .	NE-SW 31	25 N	6 W	2,625	Quaternary	Pre-Cam	Forrest Cave et al.		D. and A.[1]
2	Buffalo.	SE-NW 35	10 N	16 W	4,070	Quaternary	Arbuckle	Bell Oil & Gas Co.		D. and A.
3	Buffalo.	NE-SW 27	10 N	18 W	3,810	Quaternary	Arbuckle	Bell Oil & Gas Co.		D. and A.
4	Buffalo.	NE-NW 26	12 N	17 W	3,780	Quaternary	Arbuckle	Gled Oil Co.		D. and A.
5	Buffalo.	SW-SW 3	12 N	18 W	3,569	Quaternary	Arbuckle	Bell Oil & Gas Co.		D. and A.
6	Butler.	SE-NW 29	16 N	2 E		Quaternary		Bellwood Syndicate		Drilling
7	Dakota. . . .	NW-NE 33	28 N	8 E		Aluvium on Cretaceous		Peder Skriver et al.		Drilling
8	Dawes . . .	SW-NW 1	33 N	50 W	4,402	Cretaceous-Pierre	Pen	Chadron Oil & Gas Co.		D. and A.
9	Furnas .	SE-SE-SE 31	1 N	24 W	3,478	Quaternary on Tertiary	Pre-Cam	Helmerich & Payne		D. and A.
10	Furnas . . .	NE-NE 33	2 N	21 W	3,718	Quaternary on Cretaceous	Pre-Cam	C. W. Trickett et al.		D. and A.
11	Furnas . .	NE-NE-SE 31	3 N	25 W	3,422	Quaternary on Tertiary	Pre-Cam	Stanolind Oil & Gas Co.		D. and A.
12	Gage.	NW-SW 16	3 N	5 E		Quaternary		Ellis Oil Co.		Drilling
13	Harlan . .	SE-SE 10	1 N	19 E	4,045	Quaternary on Cretaceous	Arbuckle	Bell Oil & Gas Co.		D. and A.
14	Harlan .	NW-SE 14	2 N	18 W	3,557	Quaternary on Cretaceous	Penn	Bell Oil & Gas Co.		D. and A.
15	Harlan .	SE-SE 20	2 N	18 W	3,935	Quaternary on Cretaceous	Arbuckle	Ohio Oil Co.		D. and A.
16	Harlan. . . .	SE-NE 25	2 N	20 W	3,850	Quaternary on Cretaceous	Arbuckle	Bell Oil & Gas Co.		D. and A.
17	Nemaha. . . .	NW-NW 23	6 N	13 E	1,970	Quaternary on Permian	Dev-Hunton	Dan Short et al.		D. and A.
18	Otoe.	NE-SW-NE 25	7 N	12 E	2,532	Quaternary on Pennsylvanian	Pre-Cam	J. M. Conner et al.		D. and A.
19	Pawnee. . . .	SW-SW-SE 13	1 N	12 E	585	Alluvium on Penns.	Pre-Cam	H. W. Pieper et al.		D. and A.
20	Richardson	E½-SW-SW 3	1 N	14 E	2,191	Alluvium on Permian	Dev-Hunton	Nebr. Prod. & Ref. Co.	80(Est.)	Producer, Dawson field
21	Richardson	E½-SE-SW 3	1 N	14 E	2,199	Alluvium on Permian	Dev-Hunton	Skelly Oil Co.	27	Producer, Dawson field
22	Richardson	E½-SE-NE 9	1 N	14 E	2,237	Permian	Dev-Hunton	Uhri Oil Co.	35	Producer, Dawson field
23	Richardson	W½-NE-SW 10	1 N	14 E	2,258	Permian	Dev-Hunton	Powers Oil Co.	?	Producer-Temp. abandoned
24	Richardson.	E½-NW-NW 10	1 N	14 E	2,178	Alluvium on Permian	Dev-Hunton	Nebr. Prod. & Ref. Co.	150	Producer, Dawson field
25	Richardson.	E½-NE-NW 10	1 N	14 E	2,175	Alluvium on Permian	Dev-Hunton	Nebr. Prod. & Ref. Co.	?	Producer, Dawson field
26	Richardson	E½-SE-NW 10	1 N	14 E	2,163	Alluvium on Permian	Dev-Hunton	Powers Oil Co.	60	Producer, Dawson field
27	Richardson.	E½-SW-SW 11	1 N	14 E	2,385	Permian	Dev-Hunton	Uhri Oil Co.		D. and A.
28	Richardson.	NE-SE-SW 20	1 N	16 E	2,348	Alluv. on Pennsylvanian	Dev-Hunton	Nebr. Prod. & Ref. Co.	?	Producer, Falls City
29	Richardson.	NE-NE-NW 1	2 N	16 E		Quaternary on Pennsylvanian		Moncbia Oil Co.		Drilling
30	Richardson.	NW-NW-NE 2	2 N	15 E	2,518	Quaternary on Pennsylvanian	Dev-Hunton	Ferguson & Towle		D. and A.
31	Scotts Bluff.	NW-SW 6	20 N	54 W		Tertiary		Fuerst Oil Dev. Co.		Drilling
32	Sherman. . .	NW-SW 22	15 N	14 W	3,471	Quaternary on Tertiary	Arbuckle	Bell Oil & Gas Co.		D. and A.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1943	0	5
Number of oil wells completed during 1943	8	0
Number of gas wells completed during 1943	0	0
Number of dry holes completed during 1943	0	19

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[1] Dry and abandoned.

much valuable stratigraphic information and some noncommercial shows of oil in the Kansas City-Lansing rocks of Pennsylvanian age were secured.

No additional fields were discovered in the state during the year, and oil production dropped from approximately 1¼ million barrels during 1942 to about 688,000 bbl. during 1943. This decrease in production during 1943, although partly the result of natural decline of the older fields, was probably in part the result of a relatively low price for crude oil, which did not encourage production from many wells producing relatively large percentages of water.

One additional producer was secured in the Falls City field. The productive area of the Dawson field was enlarged by the addition of seven producers, which caused a substantial increase in production for that field. The Barada, Falls City and Shubert fields all showed rather marked declines in production.

Improved completion methods in the Dawson field secured more satisfactory wells. Most of the new wells in this field were drilled with rotary to the top of the producing formation, and the wells were cable-tooled in after the production string of casing had been set and cemented. In this manner the reservoir rock was protected from excessive penetration of drilling mud.

Oil and Gas Development in New Mexico in 1943

By John M. Kelly,* Member A.I.M.E.

New Mexico produced 38,882,342 bbl. of oil in 1943, and regained seventh place among the oil-producing states. This production was an increase of 6,968,526 bbl., or 21.8 per cent, over the figure for 1942.

The maximum per-well allowable on Jan. 1, 1943, was 38 bbl. daily and at the end of the year this figure had been increased to 48 bbl. Allocations as set by the New Mexico Oil Conservation Commission closely followed recommendations by the Petroleum Administrator for War and the average daily pipe-line runs were 106,476 bbl., being within 2.2 per cent of these allocations. Production for Lea County was 33,043,925 bbl.; Eddy County, 5,405,967 bbl.; northwestern New Mexico, 432,070 bbl., and Chaves County, 380 barrels.

Drilling activity for New Mexico in 1943 was only 75 per cent of that in 1942, with 255 completions. Of these completions 180 were oil wells, 10 gas wells and 65 dry holes. The ratio of dry holes to producers, more than 1 to 3, was the greatest in recent years. Of these dry holes, 46 were drilled within the boundaries of proven areas while 19 were wildcats.

Wildcat drilling during 1943 was responsible for the discovery of four new oil fields and one new gas field, as well as three extensions to existing proration areas. At the close of the year the New Mexico Oil Conservation Commission had designated 64 areas as proven for oil and/or gas.

Southeastern New Mexico

Lea County

The Monument area was again New Mexico's largest producing oil field, with an annual production of 7,228,855 bbl. Next was Eunice, with 6,461,044 bbl., followed by Vacuum with 4,946,110 bbl. Hobbs, ranking fourth, with 3,799,114 bbl., was the leader in total recovery with an accumulated production of 104,180,531 bbl., or more than 10,000 bbl. per acre to date.

Drilling activity in Lea County accounted for completion of 67 oil wells, 2 gas wells and 24 dry holes. One of these oil wells was the discovery well of a new area and three extended proven areas.

The most active drilling campaign in the county was again in the Maljamar area, where 18 oil wells were completed. The Maljamar Cooperative Repressuring Agreement affected 141 producing wells, and operations were a decided success, more than 85 per cent of the gas produced being returned to formation.

The new oil field for Lea County was designated as the San Simon area although boundaries have not been established to date. Discovery well for this area was the Skelly Oil Company's State U. No. 1, in the NE. NE. ¼ of sec. 5, T.22 S., R.35 E. This well was drilled to a total depth of 4183 ft. and plugged back to 4138 ft. after encountering bottom-hole water. Initial production was 124 bbl. per day on the pump. This oil is 37.4° gravity and has a sulphur content of 1 per cent. Production is from Yates sand of Permian age.

The Lynn area of southern Lea county was extended 1½ miles to the northwest

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* State Geologist, Executive member and Secretary of New Mexico Oil Conservation Commission, Santa Fe, New Mexico.

TABLE 1.—*Oil and Gas Production in New Mexico*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
									1943	
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	Com-pleted	Aban-doned
1	Anderson, *Eddy*	1940	1,280	515,698	75,647	309	45	32	0	0
2	Arrowhead, *Lea*	1938	7,920	5,921,025	1,707,168	8,370	3,546	113	2	0
3	Artesia, *Eddy*	1923	5,450	4,979,054	173,142	16,664	55	212*x*	1	1
4	Aztec-Bloomfield, *San Juan*	1924	170	41,836	445	132	50	34	0	0
5	Barber, *Eddy*	1936	920	544,344	175,575	*x*	*x*	23	2	1
6	Barker Creek Dome, *San Juan*	1942	640	0	0	1,777	845	4	1	0
7	Benson, *Eddy*	1943	120	13,583	13,583	*x*	*x*	3	3	0
8	Blanco, *San Juan*	1929	80	1,463*x*	39	375	35	1	0	0
9	Caprock, *Lea*	1940	40	2,714	784	*x*	*x*	1	0	0
10	Comanche, *Chaves*	1936	120	11,250*x*	380	*x*	*x*	3	0	0
11	Cooper, *Lea*	1929	4,680	14,657,482	780,968	117,108	5,268	114	0	4
12	Corbin, *Lea*	1938	120	48,074	12,955	*x*	*x*	3	0	0
13	Dayton, *Eddy*	1940	480	74,025	16,999	39	12	13	2	0
14	East Lusk, *Lea*	1942	240	96,552	72,444	*x*	*x*	6	0	0
15	East Maljamar, *Lea*	1942	640	63,040	57,606	82	74	16	14	0
16	Eaves, *Lea*	1929	1,080	2,181,863	346,637	12,980	3,265	27	1	0
17	Eunice, *Lea*	1928	39,440	65,279,703	6,463,503	264,994	27,044	505	0	1
18	Fenton, *Eddy*	1943	40	545	545	*x*	*x*	1	1	0
19	Fulcher Basin, *San Juan*	1934	940	0	0	2,958	1,575	10	3	0
20	Getty, *Eddy*	1928	320	773,668	75,676	*x*	*x*	11	2	0
21	Grayburg-Jackson, *Eddy*	1936	9,360	13,515,865	1,915,778	20,220	3,065	242	31	0
22	Halfway, *Lea*	1939	400	337,227	85,870	*x*	*x*	10	0	0
23	Hardy, *Lea*	1935	5,880	4,924,446	415,284	257,240	2,172	129	0	0
24	High Lonesome, *Eddy*	1939	400	25,654	3,416	316	4	10	0	0
25	Hobbs, *Lea*	1928	20,200	104,179,111	3,797,694	215,211	5,904	270	0	1
26	Hogback, *San Juan*	1922	160	2,206,227	44,532	*x*	*x*	7	0	0
27	Hospah, *McKinley*	1927	620	980,157	298,360	*x*	*x*	30	1	0
28	Jal, *Lea*	1927	1,920	6,488,172	151,991	44,254	3,149	48	0	2
29	Kutz Canyon, *San Juan*	1927	2,520	0	0	15,732	1,404	17	0	0
30	Langlie, *Lea*	1927	6,920	8,615,467	905,036	101,225	17,935	151	1	0
31	Leo, *Eddy*	1939	280	95,461	19,349	35	7	7	0	0
32	Leonard, *Eddy*	1929	2,120	1,284,021	270,625	1,583	144	53	15	0
33	Loco Hills, *Eddy*	1939	8,560	7,821,150	1,285,654	9,994	1,283	212	11	0
34	Lynch, *Lea*	1929	440	6,264,809	130,379	*x*	*x*	16	0	0
35	Lynn, *Lea*	1929	2,200	1,915,669	330,617	14,895	2,805	51	8	0
36	*Maljamar*	1926	8,360	7,199,576	1,739,735	19,358	1,382	208	18	0
37	Mattix, *Lea*	1936	8,440	7,768,531	748,671	55,065	10,660	182	2	0
38	McMillan, *Eddy*	1938	80	484	0	*x*	*x*	2	0	0
39	Monument, *Lea*	1934	37,040	58,775,201	7,234,703	153,174	13,730	514	1	0
40	North Lynch, *Lea*	1929	80	1,045,091	6,378	43	4	2	0	0
41	North Maljamar, *Lea*	1939	40	2,917	0	*x*	0	1	0	0
42	Penrose, *Lea*	1935	13,460	8,349,447	612,388	46,181	5,061	194	0	0
43	Rattlesnake, *San Juan*	1924	680	4,657,387	58,084	*x*	*x*	80	2	0
44	Red Lakes, *Eddy*	1924	3,560	680,259	72,876	807	76	88	2	2
45	Red Mountain, *McKinley*	1933	20	3,370*x*	750*x*	*x*	*x*	7	0	0
46	Rhodes, *Lea*	1928	2,540	702,452	183,738	56,781	5,537	44	5	0
47	Robinson, *Eddy*	1926	560	457,108	31,211	183	12	14	0	0
48	Russell, *Eddy* { Gas Oil	1941 1942	440	34,768	29,933	*x*	*x*	11	6	0
49	Salt Lake, *Lea*	1941	320	146,036	77,105	*x*	*x*	8	0	0
50	San Simon, *Lea*	1943	40	2,236	2,236	*x*	*x*	1	1	0
51	Shugart, *Eddy*	1938	1,440	838,960	174,319	392	87	36	0	0
52	Skaggs, *Lea*	1936	120	118,240	22,152	342	57	3	0	0
53	Skelly, *Lea*	1936	6,640	3,392,557	325,510	16,389	2,680	100	0	0

[b] Footnotes to column heads and explanation of symbols are given on page 270.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
1	15	8	0	x	x	0	36.0	0.9	Grayburg, Per	S	x	2,527	x	A	San Andres, Per	3,634
2	112	1	0	1,460	1,294	0	36.0	1.0	Grayburg, Per	D	Cav	3,720	80	A	San Andres, Per	3,960
3	4	165	3	x	x	0	35.0	1.04	Yates, Queen, Grayburg, Per	S & L	x	460 1,875	25	A	San Andres, Per	4,035
4	0	13	2	x	x	0	55.0	0.1	Farmington sand, CreU	S	x	750	25	S	Lewis shale, CreU	2,665
5	0	19	1	550x	450x	0	20.5	0.9	Yates, Per	L	Cav	1,480	x	A	Seven Rivers, Per	1,953
6			4	x	x	0			Dakota sand, CreU	S	x	2,350	50	D	McElmo, CreL	3,285
7	0	3	0	x	x	0	26.0	0.9	Yates, Per	L	x	1,760	50	A	Queen, Per	2,988
8	1	0	1	1,200	900	0	54.0	0.13	Mesa Verde, Pictured Cliffs, CreU	S	x	4,250	5	H	Mesa Verde, CreU	4,550
9	0	1	0	x	x	0	36.0	1.0	Seven Rivers, Per	S	x	3,025	27	A	San Andres, Per	4,085
10	0	3	0	x	x	0	28.5	0.9	San Andres, Per	L	x	x	x	ML	San Andres, Per	1,400
11	29	55	5	1,398	x	0	29.9	1.5	Seven Rivers, Per	D	Cav	3,542	55	A	L. San Andres, Per	5,095
12	0	2	0	1,398	x	0	30.5	1.0	Queen, Per	S	x	4,258	45	A	Grayburg, Per	5,118
13	9	0	0	x	x	0	37.0	0.9	Grayburg, San Andres, Per	LS	Fis	1,096	50	A	San Andres, Per	2,545
14	0	6	0	x	x	0	24.1	0.9	Yates, Per	L	x	2,702	25	A	Seven Rivers, Per	2,820
15	13	2	0	x	x	0	35.5	0.9	Grayburg, San Andres, Per	L & LS	x	4,187	75	A	San Andres, Per	4,805
16	11	14	2	x	x	0	28.5	1.0	Yates, Seven Rivers, Per	S & L	x	3,170	x	A	Seven Rivers, Per	3,542
17	404	81	1	1,400	928	0	33.8	1.28	Grayburg, Per	D	Cav	3,800	75	A	San Andres, Per	4,404
18	0	1	0	x	x	0	43.0	0.6	Delaware, Per	S	x	2,638	10	A	Delaware, Per	3,525
19			10	576	x	0			Pictured Cliffs, CreU	S	x	1,800	160	H	Pictured Cliffs, CreU	2,136
20	0	7	0	x	x	0	24.0	0.9	Yates, Per	LS	x	1,361	20	A	Bone Spring, Per	6,683
21	182	46	2	x	x	0	35.5	0.94	Queen, Grayburg, San Andres, Per	S & L	x	3,586	45	A	San Andres, Per	4,383
22	0	6	0	x	x	0	28.6	0.9	Yates, Per	LS	x	2,590	25	A	Queen, Per	4,005
23	81	40	0	1,400	x	0	35.0	0.9	Grayburg, Per	D	Cav	3,710	53	A	San Andres, Per	3,872
24	0	3	1	x	x	0	34.9	1.56	Queen, Grayburg, Per	LS	x	2,610	40	A	San Andres, Per	3,163
25	208	43	2	1,550	1,165	0	34.5	1.0	San Andres, Per	D	Cav	3,950	124	A	San Andres, Per	4,500
26	7	0	0	560	560	0	60.0	0.1	Dakota sand, CreU	S	x	705	9	D	McElmo, CreL	1,225
27	0	30	0	x	x	0	29.0	0.15	Hospah sand, CreU	S	26	1,639	11	DF	Dakota, CreU	3,282
28	7	11	16	x	x	0	36.0	1.0	Seven Rivers, Per	LS	x	3,303	31	A	San Andres, Per	4,125
29			17	565	400	0			Pictured Cliffs, CreU	S	x	1,840	60	H	Mesa Verde, CreU	4,400
30	101	20	16	1,450	x	RP	38.0	0.9	Seven Rivers, Per	S	x	3,350	x	A	Pre-Cam. Granite	9,594
31	0	5	0	x	x	0	35.8	0.94	Grayburg, Per	S	x	3,170	x	ML	San Andres, Per	3,857
32	30	9	8	x	x	0	36.0	0.9	Grayburg, San Andres, Per	S	x	2,808	50	A	San Andres, Per	3,591
33	162	35	0	950	452	PM	36.5	0.9	Grayburg, Per	S	x	2,620	80	A	San Andres, Per	3,453
34	0	9	0	x	x	0	30.0	1.0	Yates, Seven Rivers, Per	D	Cav	3,760	17	A	Queen, Per	4,046
35	22	16	4	1,365	x	0	29.0	1.0	Seven Rivers, Per	D	Cav	3,576	x	A	San Andres, Per	5,095
36	170	18	0	x	x	RP	38.0	0.9	Queen, Grayburg, San Andres, Per	L & S	x	3,965	x	A	L. San Andres, Per	5,150
37	126	40	9	1,400	x	0	37.3	1.0	Yates, Seven Rivers, Per	S	x	3,500	45	A	San Andres, Per	4,200
38	0	1	0	x	x	0	29.0	1.0	Queen, Per	S	x	1,200	x	A	San Andres, Per	3,305
39	477	20	0	1,427	1,223	0	34.1	1.2	Grayburg, San Andres, Per	D	Cav	3,829	89	A	San Andres, Per	4,534
40	0	2	0	x	x	0	30.0	1.0	Yates and Seven Rivers, Per	D	Cav	3,760	17	A	Queen, Per	4,046
41	0	1	0	x	x	0	33.0	1.0	Grayburg, Per	D	x	3,875	75	A	San Andres, Per	4,097
42	139	51	0	x	x	0	35.2	1.0	Grayburg, Per	S	x	3,550	90	A	San Andres, Per	4,705
43	0	36	0	x	x	0	64.5	0.2	Dakota sand, CreU	S	x	3,550	90	A	Ignacio quartzite, Cam	7,397
44	0	46	16	x	x	0	36.2	0.9	Yates, Queen, Grayburg, Per	L & S	x	465 1,904	x	A	San Andres, Per	2,905
45	0	6	0	x	x	0	42.0	0.1	Mesa Verde, CreU	S	x	438	13	AF	Mesa Verde, CreU	640
46	20	2	6	1,397	x	0	35.0	1.0	Seven Rivers, Per	S	x	3,056	x	A	Pennsylvanian	8,859
47	0	10	0	x	x	0	34.5	0.9	Grayburg, Per	S	x	3,919	80	A	San Andres, Per	4,359
48	0	9	0	x	x	0	38.0	0.8	Yates, Per	S & L	x	788	x	A	San Andres, Per	2,500
49	0	8	0	x	x	0	26.0	0.9	Yates, Seven Rivers, Per	LS	x	3,018	48	A	Queen, Per	3,825
50	0	1	0	x	x	0	36.0	1.0	Yates, Per	S	x	3,935	23	A	Yates, Per	4,183
51	21	12	0	x	x	0	33.0	0.9	Yates, Queen, Per	S	x	3,450	x	A	San Andres, Per	4,890
52	2	1	0	x	x	0	36.0	1.0	Grayburg, Per	L	x	3,800	60	A	San Andres, Per	4,757
53	24	60	3	1,420	x	0	37.4	1.0	Grayburg, Per	S	x	3,525	x	A	San Andres, Per	4,052

by the Repollo Oil Company's State 157-F No. 1, in NE. NE. ¼ of sec. 17, T. 23 S., R. 36 E. Operators reported an initial production of 210 bbl. oil in 6 hr., flowing through open 2-in. tubing with a gas-oil ratio of 1064 cu. ft. per barrel. The well was completed at a total depth of 3775 ft. in the Seven Rivers formation of Permian age.

A second extension in Lea county was in the East Maljamar area. C. T. McLaughlin et al. drilled their State No. 1 in the NW. NE. ¼ of sec. 6, T. 17 S., R. 33 E., the well being 3 miles north of the nearest production. This well pumped an initial production of 96 bbl. oil per day from a total depth of 4234 ft. in the Grayburg formation of Permian age.

Maljamar Oil and Gas Corporation extended the South Maljamar area 3½ miles to the southeast with its Cheasman No. 2-X, in the NE. NE. ¼ of sec. 22, T. 18 S., R. 32 E. This well, although called an extension to South Maljamar, was in reality on a separate geologic structure from the rest of the field. Completed at a total depth of 4840 ft., the well was plugged back to 4795 ft. after drilling into water. Initial production was 75 bbl. oil per day on the pump from the Grayburg formation of Permian age.

The deepest well drilled to date in New Mexico was completed during 1943. This was the R. H. Olsen et al. Langlie No. 1, in the SE. SE. ¼ of sec. 11, T. 25 S., R. 37 E., which was drilled to a total depth of 9594 ft. in pre-Cambrian granite after testing the Ellenburger formation of Ordovician age. Although the operators encountered numerous shows of oil and gas in both the Permian and pre-Permian sections, the well failed to prove a commercial producer. At the close of the year the well was plugged back to 4880 ft. and shut down for orders, with some possibility of its completion as a gas well.

At the close of the year two additional Ellenburger tests were drilling and a third location had been announced. Of the two tests drilling, one, the El Paso Natural Gas Company's Ginsberg No. 1, was located in SW. NW. ¼ of sec. 7, T. 25 S., R. 38 E., and drilling at 8362 ft. in (possibly) the Pennsylvanian. The second drilling well, the Humble Oil and Refining Company's Leonard No. 1, SW. SW. ¼ of sec. 12, T. 26 S., R. 37 E., was drilling at 8859 ft. in the Devonian

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
									1943	
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned
54	South Eunice, *Lea*	1930	4,520	6,425,841	925,158	23,973	5,583	111	10	0
55	South Lovington, *Lea*	1938	4,360	2,229,814	597,235	1,843	583	46	2	0
56	South Maljamar, *Lea*	1939	280	128,187	50,455	51	38	7	1	0
57	Square Lake, *Eddy*	1941	5,240	1,387,635	1,031,259	1,763	1,547	131	35	0
58	Table Mesa, *San Juan*	1925	100	638,634	29,860	*x*	*x*	6	0	0
59	Tocito Dome, *San Juan*	1943	40	0	0	0	0	1	1	0
60	Turkey Track, *Eddy*	1943	40	725	725	*x*	*x*	1	1	0
61	Ute Dome, *San Juan*	1921	640	0	0	9,027	925	3	0	0
62	Vacuum, *Lea*	1929	28,000	21,522,139	4,946,619	17,970	4,245	387	3	0
63	West Eunice, *Lea*	1928	760	786,863	312,906	29	22	19	0	0
64	West Lusk, *Eddy*	1941	120	53,319	39,655	*x*	*x*	3	1	0
			254,660	381,207,132*x*	38,882,342*x*	1,497,483	131,929	4,382	190	12

shale. Continental Oil Co. et al. were building derrick for a projected Ellenburger test in SW. NW. ¼ of sec. 23, T. 20 S., R. 37 E.

Eddy County

The largest producing field in Eddy County during 1943 was Grayburg-Jackson, with 1,915,778 bbl. This area still led in total recovery, with 13,515,865 bbl. The year's second largest producing area was Loco Hills, with a total of 1,285,654 bbl. Square Lake, during its third year of production, was in third place with 1,031,287 barrels.

The Loco Hills Pressure Maintenance project was operating without too much success, approximately 40 per cent of the gas produced being returned to the producing horizon. At the request of interested operators, the New Mexico Oil Conservation Commission had set a top allowable of 25 bbl. oil per well and a maximum gas-oil ratio of 2000 cu. ft. per barrel for this field.

A second repressuring project for Eddy County was under construction by the Grayburg Oil Co. and associates. This installation will affect a large number of the wells in the Grayburg-Jackson area.

New Mexico's most active drilling campaign for the year was in the Square Lake field, where completions totaled 34 oil wells, 1 gas well and 1 dry hole. Nine drilling rigs were running as of Dec. 21, 1943. Closely following in the number of completions was Grayburg-Jackson area, with 31 oil wells and 3 dry holes.

One of the deepest tests to date for the county was being drilled by S. P. and Martin Yates, Jr., in NW. NE. ¼ of sec. 5, T. 17 S., R. 30 E. This well was drilled with cable tools to a total depth of 6587 ft. in the Abo formation of Permian age, where the operators contemplate rigging up rotary tools to complete the test of pre-Permian formations.

Three new oil fields were discovered in Eddy County during 1943, of which the most important was the Benson area. This area was discovered by the H. E. Yates, Snowden and McSweeney No. 1, SE. NW. ¼ of sec. 16, T. 19 S., R. 30 E. Initial production was 120 bbl. oil plus 432 bbl. water per day on pump from a total depth of 1836 ft. in Yates lime of

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
54	77	7	3	1,455	1,096	0	33.0	1.0	Seven Rivers, Per	D	Cav	3,775	70	A	Yeso, Per	6,202
55	35	8	1	1,670	1,048	0	33.0	1.0	San Andres, Per	L	*x*	4,350	*x*	A	San Andres, Per	5,501
56	4	2	0	*x*	*x*	0	33.5	1.0	Queen, Grayburg, Per	L & S	*x*	3,946	62	A	San Andres, Per	4,840
57	128	1	0	950	760	0	37.8	0.8	Grayburg, Per	S	*x*	3,012	25	A	Abo, Per	6,587
58	0	6	0	*x*	*x*	0	57.0	0.03	Dakota sand, CreU	S	*x*	1,325	12	A	Chinle, TriU	3,010
59	0	0	0	2,460	2,460	0			Ouray lime, Dev	L	*x*	6,659	21	D	Ignacio Quartzite, Cam	6,919
60	0	1	0	*x*	*x*	0	37.0	0.9	Queen, Grayburg, Per	L & S	*x*	2,575	75	A	Grayburg, Per	2,815
61			3	720	440	0			Dakota sand CreU	S	*x*	2,285	60	D	Dakota, CreU	2,590
62	226	119	0	1,630	1,117	0	35.5	1.0	San Andres, Per	D	Cav	4,316	*x*	A	San Andres, Per	5,329
63	5	14	0	1,300	*x*	0	31.0	1.0	Seven Rivers, Per	L	*x*	3,773	51	A	San Andres, Per	4,695
64	0	3	0	*x*	*x*	0	26.0	0.9	Yates, Per	L	*x*	2,509	20	A	Seven Rivers, Per	2,763
	2,848	1,139	136													

TABLE 2.—*Summary of Drilling Operations in New Mexico*

Important Wildcats Drilled in 1943

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Remarks
		Sec.	Tp.	Rge.					Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		
1	De Baca	26	1 S	26 E	2,035	Per	Yeso Per	Danciger Oil & Ref. Co.				Dry hole
2	De Baca	8	2 S	26 E	1,890	Per	Yeso Per	Danciger Oil & Ref. Co.				Dry hole
3	Eddy	19	17 S	31 E	2,040	Ter	Queen Per	Fren Oil Co.	46	?	2	New producing horizon Grayburg-Jackson area
4	Eddy	36	18 S	26 E	1,500	Per	San Andres Per	R. E. McKee & Stanley Jones				Dry hole
5	Eddy	28	19 S	27 E	951	Per	Queen Per	Trumter Oil Corp.				Dry hole
6	Eddy	3	19 S	29 E	2,815	Ter	Grayburg Per	R. E. McKee	12 bo. +5 bw.	Pump		Discovery well, Turkey Track
7	Eddy	16	19 S	30 E	1,836	Ter	Yates Per	Harvey E. Yates	120	Pump		Discovery well, Benson area
8	Eddy	10	19 S	30 E	2,988	Ter	Queen Per	Harvey E. Yates				Dry hole
9	Eddy	22	21 S	27 E	603	Per	Castile Per	J. E. Metcalf				Dry hole
10	Eddy	15	21 S	28 E	2,644	Per	Delaware Per	Schuster & Messinger	20	Pump		Discovery well, Fenton area
11	Eddy	21	21 S	28 E	3,525	Per	Deleware Per	M. Yates, III & R. Nix				Dry hole
12	Guadalupe	24	11 N	18 E	2,205	Per	Pre-Cam	Franklin Pet. Corp.				Dry hole
13	Lea	22	12 S	35 E	5,225	Ter	San Andres Per	T. F. Morrow				Dry hole
14	Lea	17	13 S	35 E	5,127	Ter	San Andres Per	B. H. Nolen				Dry hole
15	Lea	3	16 S	33 E	5,102	Ter	San Andres Per	N. G. Penrose, Inc.				Dry hole
16	Lea	18	17 S	34 E	5,050	Ter	Grayburg Per	H. P. Taubman				Dry hole
17	Lea	7	17 S	33 E	4,234	Ter	Grayburg Per	C. T. McLaughlin	96	Pump		Extension E. Maljamar area
18	Lea	22	18 S	32 E	4,840	Ter	San Andres Per	Maljamar Oil & Gas Corp.	75	Pump		Extension S. Maljamar area
19	Lea	31	18 S	35 E	5,315	Ter	Grayburg Per	Tidewater Oil Co.				Dry hole
20	Lea	29	19 S	36 E	5,003	Ter	San Andres Per	B. H. Nolen				Dry hole
21	Lea	36	20 S	32 E	3,439	Ter	Seven Rivers Per	V. S. Welch				Dry hole
22	Lea	1	20 S	33 E	3,684	Ter	Seven Rivers Per	N. G. Penrose, Inc.				Dry hole
23	Lea	30	20 S	34 E	3,547	Ter	Yates Per	Neil H. Wills				Dry hole
24	Lea	20	20 S	35 E	4,210	Ter	Yates Per	Argo Oil Corp.				Dry hole
25	Lea	17	21 S	33 E	3,754	Ter	Yates Per	Culbertson & Irwin				Dry hole
26	Lea	10	21 S	34 E	4,075	Ter	Yates Per	Skelly Oil Co.				Dry hole
27	Lea	5	22 S	35 E	4,183	Ter	Yates Per	Skelly Oil Co.	122	Pump		Discovery well, San Simon area
28	Lea	17	23 S	36 E	3,775	Ter	Seven Rivers Per	Repollo Oil Co.	840	0.89	2	Ext. Lynn area
29	Lea	11	25 S	37 E	9,594	Ter	Pre-Cam granite	R. H. Olsen et al.				P. B. 4885 ft. S.D.O.
30	McKinley	3	14 S	10 W	926	Cre	Cretaceous	Ambrosia Investors Co.				Dry hole
31	Otero	5	26 S	16 E	2,175	Per	Pre-Cam granite	Hunt Oil Co.				Dry hole
32	Quay	25	8 N	30 E	6,747	Per	Pre-Cam granite	Stanolind Oil & Gas Co.				Dry hole
33	Roosevelt	21	2 S	20 E	3,445	Ter	Queen Per	W. J. Peterman				Dry hole
34	Roosevelt	1	7 S	37 E	5,278	Ter	Yeso Per	Malco Refineries, Inc.				Dry hole
35	Rio Arriba	3	27 N	2 E	2,009	Per	Pre-Cam quartzite	Helmerich & Payne				Dry hole
36	San Juan	17	26 N	18 W	6,919	Per	Ignacio quartzite, Cam.	Conoco et al.	2.6 (gas 98% Ni)			Discovery well, Tocito Dome
37	San Juan	13	30 N	21 W	4,840	Per	Ignacio quartzite, Cam	Conoco et al.				Dry hole
38	Sierra	8	14 S	2 W	507	Cre	Cretaceous	C. R. Wofford				Dry hole

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1943	65	19
Number of oil wells completed during 1943	176	4
Number of gas wells completed during 1943	9	1
Number of dry holes completed during 1943	47	20

Permian age. At the end of the year there were three producing wells in the area. The oil varies from 24° to 32° gravity and has an asphalt base. The second discovery for Eddy County was the Turkey Track area, discovered by the Robert E. McKee State No. 2 in SE. SE. ¼ of sec. 3, T. 19 S., R. 29 E. This well was drilled to a total depth of 2815 ft. and plugged back to 2710 after encountering bottom-hole water. Operators reported an initial production of 12 bbl. oil plus 5 bbl. water per day on the pump. The production is from the lower Queen and upper Grayburg formations of Permian age. A second well was drilling in the area at the close of the year. Another newly discovered field was designated the Fenton area, embracing all of T. 21 S., R. 28 E. The only successful well drilled to date is Schuster and Messinger's Page No. 1, SW. NW. ¼ of sec. 15, T. 21 S., R. 28 E. Completed at a total depth of 2649 ft., the well pumped at the rate of 20 bbl. oil per day from the Delaware sand of Permian age. The oil is of 43° gravity.

NORTHWESTERN NEW MEXICO

Hospah Dome was again the leading producing field in northwestern New Mexico, with 300,810 bbl., followed by Rattlesnake with 58,084 bbl. Fulcher Basin was the leader in gas production, with 1,575,000,000 cu. ft. Only two oil wells were completed in this area during the year, one in Hospah and one in Rattlesnake. Of the six gas wells completed, three were in Fulcher Basin.

The one discovery for northwestern New Mexico was drilled on Tocito Dome by Continental Oil Co. et al. The well was bottomed at 6919 ft. in Ignacio quartzite of Cambrian age. Plugged back to 6680 ft. the well gauged 2,600,000 cu. ft. gas per day. The gas was reported to contain 98 per cent nitrogen and was shut in with a pressure of 2460 lb. per sq. in. Production is from the Ouray lime of Devonian age. A failure on Biclahbito Dome was drilled by Continental Oil Co. et al. to a total depth of 4840 ft. in Ignacio quartzite of Cambrian age.

The U. S. Government drilled a well in the Rattlesnake area which was completed at a total depth of 7049 ft. with a reported initial production of 17,000,000 cu. ft. gas per day. Rock pressure was 2980 lb. per sq. in. and the gas, from Ouray lime of Devonian age, is reported to contain an appreciable amount of helium.

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Oil and Gas Developments in New York for 1943

By C. A. Hartnagel*

The year 1944 marks the eightieth anniversary of the discovery of petroleum by drilling in New York State. It was in 1864 that a half dozen shallow wells were drilled at Limestone in Cattaraugus County, in a region that now forms the northern extension of the 82,000-acre Bradford pool. These early wells found oil, but not in paying quantities. They did, however, attract attention to the district and were a factor in the development of the still active Bradford pool of Pennsylvania and New York.

During 1943, the production of petroleum in New York amounted to 5,029,000 bbl. This represents a decrease over the previous year, in which 5,421,000 bbl. was produced.

The flush production for the New York fields occurred in the early eighties shortly after the discovery of oil in the Richburg pool of Allegany County. During the flush period, production was in excess of five million barrels annually. By 1887, however, the output had decreased to an amount only slightly more than two million barrels, and through the early years of the present century the annual total was often less than one million barrels. Flooding of the oil sands for increasing production was made legal in 1919, and in 1927 the output once more reached the two million mark. Two years later it had increased to over three million barrels.

In Table 1 is shown production since 1935, in which year for the first time the output under flooding methods was in excess of four million barrels. From this table, it is evident that oil production in New York is rather well stabilized, and since most of the oil is obtained by the flooding, or water-drive, method, with little or no prospect of discovery of new oil territory, rapid changes in yield from year to year are not to be expected.

Table 1.—*Oil Production in New York since* 1935

Year	Production, Bbl.
1935	4,236,000
1936	4,663,000
1937	5,478,000
1938	5,045,000
1939	5,098,000
1940	4,999,000
1941	5,185,000
1942	5,421,000
1943	5,029,000

In thickness, the oil sands have a maximum of about 50 ft., and by means of flooding may produce 10 to 12 thousand barrels an acre and proportional amounts for thinner sands. In some cases, floods have been developed in sands only 12 ft. thick. Under good flooding conditions a yield of 2000 bbl. an acre is about the lower limit at which oil can be produced at the present price of $3.00 a barrel.

The average cost for the physical development of a lease, not including the cost of the lease itself, is $5000 an acre. Since several months must intervene before the flood begins to act on the oil wells, and a year or more is required to bring the wells to maximum daily production, it is evident that a considerable interval occurs before maximum returns are realized. Once a flood is developed and the wells

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begin to yield, it is essential that production be maintained.

From the standpoint of investment, the number of years necessary to water out a sand is an important consideration. In some sands, most of the oil can be obtained within 10 years, but in certain tight sands the flooding period may require 20 years, and thus greatly reduce or even eliminate any profits. Nearly every lease is a problem in itself, and should receive careful engineering study and laboratory examination of the sand before the development of the lease is undertaken.

Natural Gas

Efforts to obtain new supplies of natural gas from the Oriskany sandstone were continued in New York during 1943, but without noteworthy results. During the year, 26 wildcat wells were drilled (Table 2). In Allegany County, six wells, one in each of the townships of Andover, Angelica, Belfast, Bolivar, Wellsville, and Willing, were drilled, but none were productive. Four of the wells were over 4600 ft. deep. In Steuben County, bordering Allegany County on the east, nine wells distributed in five townships were completed as dry holes. Four of the wells were more than 5000 ft. deep, and three over 4000 ft. In Chemung County, directly east of Steuben, where the Oriskany lies about 3000 ft. below the surface in the lowlands, five wells were drilled without finding any gas. In Tompkins County, lying northeast of Chemung County, four wells were drilled to the Oriskany. Two of these, in Groton Township, were successful. The first had an initial daily production of 1,000,000 cu. ft. of gas, the other 2,500,000 and constituted the only initial Oriskany production of the year. One Oriskany well drilled during 1943 was in the town of Orange, Schuyler County. The well was bottomed at a depth of 2902 ft., but no Oriskany sandstone was found.

There have been no important changes in operating technique in any of the New York oil or gas fields. The practice of underground storage of natural gas in depleted fields for peak winter use is being extended. This type of storage, used as early as 1918 in the Silurian rocks of Erie County, has now been successfully applied to the Oriskany sands of Devonian age, some of which lie more than 4000 ft. below the surface.

Of considerable interest is a deep test in the Woodhull field of Steuben County, which is being made to the Silurian and perhaps the Ordovician formations, and already has reached a depth of over 6000 ft. A previous deep test in Erwin township, Steuben County, some 14 miles to the northeast of Woodhull field, reached a depth of 6825 ft., but was unproductive.

Previous to the discovery of gas in the Oriskany sandstone in 1930, the bulk of natural-gas production in New York State came partly from the Medina sandstone of western New York, which is of Silurian age; and to a lesser extent from the relatively shallow formations of Devonian age in southwestern New York, which include the oil-producing sands of Cattaraugus and Allegany Counties. In addition, the Trenton limestone of Ordovician age contributed substantial quantities to the annual production from fields lying near the east end of Lake Ontario.

For many years before the discovery of natural gas in the Oriskany sandstone, the production for the state as a whole averaged about seven billion cubic feet yearly. The increase in annual production due to new supplies from the Oriskany first became evident in the 1935 total, when New York's gas production increased from seven billion to over eight billion cubic feet. Following the discovery of Oriskany gas in the Greenwood, State Line, Woodhull and Beech Hill fields, the annual yield rose rapidly until, in 1938, the state total reached a maximum of 39 billion cubic feet.

TABLE 2.—*Wildcat Oriskany Tests in New York State in* 1943

County and Township	Name of Well	Operator	Elevation, Ft.	Tully, Ft.	Top Onondaga, Ft.	Top Oriskany, Ft.	Total Depth, Ft.	Remarks
Allegany								
1. Andover	H. G. Clark No. 2	Belmont Q. D. and Empire Prod. Corp.	1,891	3,957	4,566	4,614	4,617½	100 M cu. ft. gas. Hole filled 650 ft. salt water in 14 hr. with gas testing 75 M cu. ft. Pressure of 750 lb. Abandoned
2. Angelica	Grace Conrad	Allegany Gas Co.	1,787	3,108–3,166	3,643	3,742	3,806	Oriskany 3742–3759 ft. No gas; no water
3. Belfast	B. E. Barringer No. 2	Appalachian Dev. Co.	1,438	2,454–2,481	2,936	3,002	3,096	No gas or s. w. Few grains of sand at 3002 and at 3052 ft. Abandoned
4. Bolivar	J. H. Gadsby	Allegany Gas Co. and Empire Prod. Corp.	2,020	4,359–4,403	4,872	4,937	4,973	Oriskany sand grains from 4937–4955 ft. 20 M cu. ft. gas at 1502–1515 ft.
5. Wellsville	DeForest Genung	Allegany Gas Co., Empire Prod. Corp. and Hanley and Bird	2,163	4,312–4,362	4,870	4,899	4,900	18 M cu. ft. gas and 2600 ft. s. w. Abandoned
6. Willing	Clarence Johnston No. 2	Cunningham and Coyle	2,191	4,248–4,295	4,888	4,895	4,897	50 M cu. ft. gas at 708 ft. 36 M cu. ft. gas at 4895 ft. and 2000 ft. s. w.
Steuben								
7. Cameron	Steuben Co. No. 2	D-Y-M Corp.	1,657	3,273–3,318	3,996	4,021	4,030	No show of gas, but s. w. at 4030 ft.
8. Cameron	Glen Boyd No. 3	N.Y.S.N.G.	1,516	3,142–3,191	3,873	3,894	3,908	260 M cu. ft. gas and 1700 ft. s. w. at 3902 ft.
9. Greenwood	Mary Rogers	Hanley and Bird and Empire Prod. Corp.	2,329	4,195–4,238	4,847	4,888	4,891	No gas. At 4891 ft. s. w. at rate of 5 bailers per hour
10. Jasper	George Murphy	N.Y.S.N.G.	1,712	3,462–3,509	4,165	4,187	4,205	At 4197 ft., hole filled 900 ft. with s. w. 22 hr
11. Troupsburg	Roger Lozier	N.Y.S.N.G.	2,092	4,378–4,430	5,307	5,340–5,363	5,364	83 M cu. ft. gas in Tully at 4386 ft. and 4427 ft.; tested 64 M cu. ft. following day; 20 M at completion. Abandoned
12. West Union	Charles Lewis No. 1	Allegany Gas Co.	2,196	4,482–4,534	5,150	5,184	5,255	After shot 18 M cu. ft. gas; s. w. at rate of 1 bbl. before shot, increased; well abandoned
13. West Union	Jessie Lewis No. 1	Belmont Q. D.	2,279	4,502–4,565	5,170	5,210	5,216	S. W. at 5210–5211 ft. and at 5213–5214 ft. Abandoned
14. West Union	Harriet Joyce No. 1	Penn York	2,204	4,345–4,392	4,993	5,028–5,058	5,097	No gas; no s. w.
15. West Union	Ed. P. Dailey	Belmont Q. D. and Allegany Prod. Corp.	2,287	4,360	5,044	5,072	5,076	At 5072–5075 ft., hole filled with 1000 ft. s. w. in 8 hr.
Chemung								
16. Erin	Marie Struzinsky No. 1	Allegany Gas Co.	1,605	2,483–2,573	3,732	3,782–3,853	4,030	Well shot; small flow. Abandoned
17. Elmira City	Leonard Baker	Updegraff	856	1,454–1,541	2,732	2,743–2,753	2,753	150 M cu. ft. gas at 2750 ft.; 2000 ft. s. w. at 2753. Abandoned
18. Veteran	Jennie Earl	D-Y-M Corp.	989	1,518			1,541	Abandoned. Fault well
19. Veteran	Herbert May	D-Y-M Corp.	937	1,528	2,680	2,717–2,751	2,754	No gas or water
20. Veteran	A. M. Beebe	D-Y-M Corp.	1,339	1,773–1,834	2,956	3,027	3,075	6 M cu. ft. gas at 3030 ft. Abandoned
Tompkins								
21. Dryden	Vance Nesbit	Belmont Q. D.	1,402	868–909			1,013	Abandoned because of datum in Tully
22. Groton	James O. Robertson	Belmont Q. D.	1,396	817–834	2,049	2,115	2,123	First gas, 990 M cu. ft. at 2117 ft. I.R.P. 510 lb. in 24 hr.; 1000 M cu. ft. gas through 2⅛-in. tubing
23. Groton	Archie Gagnon No. 2	Belmont Q. D.	1,361	789–823	2,010	2,075	2,082	S. W. at 1986 ft. (Cherry Valley lime). At 2082 ft. 2500 M cu. ft. gas, but s. w. spray. Hope to save well
24. Groton	Grant Smith Est.	N.Y.S.N.G.	1,254	690–728	1,910	1,977	1,987	Show gas at 1982; at 1985–1987 ft. s. w. filled 160 ft. in 1 hr. Abandoned
25. Newfield	Frank Gillette	Belmont Q. D.	1,564	1,517–1,581	2,794	2,867	2,912	Oriskany horizon only; no gas, no water
Schuyler								
26. Orange	Thomas Button	N.Y.S.N.G.	1,272	1,747–1,789	2,740	2,792–2,804	2,902	No gas or water; Oriskany hard, limy

Since that time, with the gradual exhaustion of the fields and failure to find new pools, production has declined, totaling less than nine billion cubic feet of gas in 1942. Thus the annual volume is rapidly receding toward the seven billion average produced previous to the discovery of Oriskany gas. The present annual yield represents not only the effect of the marked decrease in Oriskany gas, but also the gradual falling off in the older gas fields—the Medina, Trenton and older Devonian wells.

TABLE 3.—*Production of Natural Gas in New York since* 1935

Year	Production, M Cu. Ft.	Value	Price, Cents per M Cu. Ft.
1935........	8,288,000	$ 5,909,000	71.5
1936........	12,431,000	8,645,000	69.5
1937........	21,325,000	12,388,000	58.1
1938........	39,402,000	18,324,000	46.5
1939........	29,222,000	15,201,000	52.0
1940........	12,187,000	8,246,000	67.7
1941........	10,456,000	7,852,456	75.1
1942........	8,718,000	6,498,000	74.5

In Table 3 is shown the rise and decline of natural-gas production in New York State since 1935. The values represent the prices paid at points of distribution, mostly within the state, before the gas is distributed through the city mains.

From its favorable location as regards markets, any natural gas produced in New York finds a ready sale, and efforts are being continued to obtain new supplies in the Oriskany. At the beginning of 1944, nine wells were being drilled to the Oriskany sand.

Oil and Gas Development in Ohio in 1943

By Kenneth Cottingham,* Member A.I.M.E.

The number of wells drilled in Ohio in 1943 was slightly in excess of the number drilled in 1942. Compared with the average annual completions for the five years preceding, the year 1943 was short 11 per cent, but the average initial volume of gas wells was considerably improved. In 1942 the average initial open flow per gas well was 668 M cu. ft., whereas in 1943 the average was 913 M cu. ft. Although no large gas-producing areas were discovered during the year under review, some 30 small pools were found in 17 of the counties of eastern Ohio. These new pools averaged about 300 acres each, and most of them were not extensions but were separate pools adjacent to older production. The Clinton sand furnished most of these discoveries, although six were from the Berea, one was Newburg, and three were shallow sands. No discoveries were made outside former producing counties, and there was no new development in the Trenton area of western Ohio.

The number of oil wells decreased from 181 drilled in 1942, to 170 in the year 1943. The production of Pennsylvania-grade oil increased 7644 bbl. The total Corning production, however, decreased 91,325 bbl. The present price of Corning-grade oil, $1.31 per bbl., is too low, in the opinion of the operator, to justify exploration. Until something is done in correcting the price level of Corning grade, the production probably will continue to decline. The oil industry in Ohio is making a concentrated effort toward increased production and improved methods of recovering Pennsylvania-grade oil, and as this report is written a research and engineering program is being formulated for the benefit and information of the various producers of that grade in Ohio.

Table 1.—*Wells Drilled during* 1943 *in Ohio*

Sand	Oil Wells		Gas Wells		Number of Dry Holes	Total Number Drilled
	Number of Wells	Average Initial Daily per Well, Bbl.	Number of Wells	Average Initial Daily per Well, Bbl.		
Shallow	32	16	57	471	72	161
Berea	44	7	89	214	82	215
Ohio Shale			12	124	2	14
Oriskany	1	40	17	1,392	5	23
Newburg			4	661	1	5
Clinton	86	66	276	1,237	223	585
Trenton	7	14			5	12
Sub-Trenton					1	1
Total	170	39	455	913	391	1,016

General Activity

The most active county from the viewpoint of number of wells was Perry, where

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55 oil wells were drilled, 33 of which were in the Clayton pool, discovered in 1936. In addition to the 33 oil wells, 3 gas wells and 11 dry holes were drilled within this pool during 1943. The largest oil well during the year had an initial of 270 bbl. per day. No additional acreage was proved, and the total at the end of 1943 was 4200 acres.

TABLE 2.—*Completions in Ohio in 1943*

County	Oil Wells	Gas Wells	Dry Holes	Total
Ashland	5	22	14	41
Athens	10	27	36	73
Belmont			2	2
Carroll	4		2	6
Columbiana	1	1	7	9
Coshocton	8	8	11	27
Cuyahoga	1	1	2	4
Fairfield	1	5	4	10
Fulton		9	1	10
Gallia		5	5	10
Guernsey	2	20	8	30
Hancock			1	1
Harrison	3	0	1	4
Henry	2			2
Hocking	2	8	4	14
Holmes	1	26	17	44
Jackson			1	1
Jefferson	1	0	5	6
Knox	5	5	13	23
Lake			1	1
Lawrence		4	5	9
Licking	2	5	4	11
Lorain		29	24	53
Mahoning			2	2
Medina	3	38	14	55
Meigs	4	26	11	41
Mercer	2		1	3
Monroe	9	11	10	30
Morgan	5	53	25	83
Muskingum	14	35	26	75
Noble	21	3	26	50
Perry	55	22	42	119
Preble			1	1
Richland		7	3	10
Stark		25	7	32
Summit		13	9	22
Tuscarawas		11	8	19
Vinton		1		1
Washington	6	20	23	49
Wayne		15	13	28
Wood	3		2	5
Totals	170	455	391	1,016

Morgan County had a total of 83 completions, of which 5 were oil wells, 53 gas and 25 dry. Only one oil well was important. This was completed in the Clinton sand at a depth of 4202 ft., had an initial production of 105 bbl., and was located in Bloom township. In York township, 29 gas wells were completed, the largest being a Clinton well having an initial open flow of 3675 M cu. feet.

Muskingum County was third in drilling activity, with 14 oil wells, 35 gas wells, 26 dry holes, or a total of 75 completions. The largest oil wells were in Falls, Newton and Wayne townships, the well in Falls township being described in detail later. The largest gas wells were likewise in Wayne township.

TABLE 3.—*Production of Oil in Ohio in 1943, Tabulation by Grade*

Grade	Number of Wells	Barrels
Pennsylvania	11,470	1,759,210
Lima	7,100	325,000
Corning	3,407	881,021
Cleveland-Chatham[a]	1,358	476,972
Total	23,335	3,442,203

[a] Formerly Lodi.

Athens County was active, but practically all drilling was in shallow sands—chiefly Cow Run, Macksburg, Keener, and Injun—and only five wells were drilled to the Clinton sand, three of them being dry and two being small gas wells.

The total footage drilled in completing the 625 oil and gas wells was 1,594,748 feet.

HORIZONS TESTED

As usual, more than half of the wells completed were drilled to the Clinton sand. The total depth of all such wells—oil, gas and dry—was 2,003,094 ft. None of the Clinton tests was out of the ordinary from the standpoint of location, although two deeper than average dry holes were drilled in Guernsey County. One was 5476 ft. deep in Center township. The other, in Wheeling township, was drilled originally as an Oriskany test. When found dry in that formation, drilling was resumed to a total depth of 4766 ft., where the well also was dry in the Clinton.

Only one sub-Trenton well was drilled. This was in western Ohio in Recovery township, Mercer County, and the total depth was 1643 ft. The well was dry. All the Trenton tests, with one exception, were in western and northwestern Ohio in the general area of Trenton production. The exception was in sec. 22 of Olive township, Meigs County, which is in southeastern Ohio many miles from Trenton production, and would therefore be considered a wildcat test. This well, known as the Sinclair Prairie-Longsworth, was reported to be a seismic location. It was dry in all formations, reached the top of the Trenton at 6884, and finished at a depth of 7466 ft., where it was abandoned. Total footage of all Trenton tests was 23,221.

TABLE 4.—*Number of Completions in Ohio, 1939–1943*

Year	Oil		Gas		Dry		Total
	Number	Per Cent	Number	Per Cent	Number	Per Cent	
1939	170	16.67	501	49.12	349	34.21	1,020
1940	327	26.63	491	39.98	410	33.39	1,228
1941	333	21.33	701	44.91	527	33.76	1,561
1942	181	17.95	471	46.73	356	35.32	1,008
1943	170	16.73	455	44.78	391	38.49	1,016
Total..	1,181	20.25	2,619	44.90	2,033	34.85	5,833

Of the five wells drilled to the Newburg (Silurian) limestone, four were gas wells, the largest of which was in lot 37, Brecksville township, Cuyahoga County, and had an initial open flow of 1500 M cu. ft. and an initial rock pressure of 1120 lb. Total footage drilled to the Newburg during the year was 13,983.

Most of the Oriskany wells were in Liberty and Wheeling townships, Guernsey County, where 15 gas wells and only one dry hole resulted. An Oriskany oil well having an initial production of 40 bbl. was drilled in sec. 15, Blue Rock township, Muskingum County. In Richfield township, Summit County, two Oriskany wells were completed, their combined initial open flow being 437 M cu. ft. Total Oriskany footage was 70,857.

Berea wells were drilled in 22 counties. The greatest number in any one county was Athens, with 34 wells. Total Berea drilling was 289,158 feet.

Shallow formations, which in the classification here includes about 15 horizons lying above the Berea, were the objectives of 40 wells in Washington County and 34 wells in Athens County. Total shallow sand drilling was 147,552 feet.

LOCAL DEVELOPMENT

Penfield and Wellington townships, Lorain County, lie along the western (the updip and transitional) side of the Clinton trend in northern Ohio. A gas well drilled in 1942 discovered this pool, but it was not until 1943 that the area was actively developed. Approximately 800 acres had been proved at the end of 1942, and this was extended an additional 1200 acres in 1943 by the 17 gas wells drilled during that year. A number of unusually large wells were completed, among them being wells with initials of 13 million, 12 million and 7 million cubic feet. Eight dry holes were completed here in 1943. The average Clinton depth is about 2400 feet.

TABLE 5.—*Annual Oil Production in Ohio, 1939–1943*

Year	Production, Bbl.	Number of Oil Wells	Average Per Well, Bbl.
1939	3,156,000	25,680	123
1940	3,169,000	25,500	124
1941	3,510,000	24,801	142
1942	3,664,000	24,080	152
1943	3,442,000	23,335	148

In southwestern Clinton township, Wayne County, and in adjacent Washington township, Holmes County, 12 gas wells and 3 dry holes were drilled, adding approximately 1000 acres and increasing the proved area to 5000 acres. This is a Clinton pool, and the depth of the wells is about 3100 feet.

Sandy township, Tuscarawas County, had six Clinton gas wells and two dry holes. The gas wells were not large, the best gauging only 1250 M cu. ft. when completed. These wells added 700 acres to proved territory, which is in the northeastern part of the township. The wells average 4850 ft. in depth. In the adjacent township to the north—Pike township, Stark County—21 gas wells and 3 dry holes were drilled. The average initial open flow was only 870 M cu. ft. per well, and the average Clinton depth 4800 feet.

TABLE 6.—*Annual Production and Consumption of Natural Gas in Ohio*, 1938–1942

Year	Annual Production, M Cu. Ft.	Annual Consumption, M Cu. Ft.
1938	35,257,000	108,013,000
1939	36,469,000	114,720,000
1940	40,639,000	129,856,000
1941	41,858,000	136,251,000
1942	45,055,000	146,137,000

Within the limits of an older pool in Hinckley township, Medina County, 16 gas wells were drilled during the year. The total area proved at the end of 1943 was approximately 4000 acres, and the depth of the Clinton sand is about 3350 feet.

One locality only was active in Oriskany drilling—the northward extension of the older Cambridge field, in Liberty and Wheeling townships, Guernsey County. The discovery well was completed in July 1942 in sec. 21, Wheeling township. Last year 14 gas wells and 2 dry holes were drilled, adding about 2500 acres. The average initial open flow of the gas wells, including one drilled in northeastern Knox township, was slightly over 1500 M cu. ft. per well. The Oriskany is about 3400 ft. deep.

Berea development was scattered, Athens and Morgan Counties leading in the number of wells. In northern Bedford township, Meigs County, 12 gas wells and 2 dry holes were drilled, adding about 1000 acres to proved territory and increasing the total proved area of this pool to 1500 acres. The largest well gauged slightly more than 1000 M cu. ft. The Berea sand is about 1650 ft. deep.

The most active oil-producing area continues to be the Clinton pool in northwestern Clayton township, Perry County. This pool was expanded about 600 acres during 1943. During the year, 33 oil wells, 3 gas wells, and 11 dry holes were drilled.

TABLE 7.—*Prices of Crude Oil in Ohio during* 1943

Grade	12-31-42	12-31-43
Pennsylvania	$2.55	$2.55
Lima	1.50	1.50
Corning	1.31	1.31
Cleveland-Chatham[a]	1.30	1.30

[a] Formerly Lodi.

The largest of the oil wells had an initial production of 270 bbl. This oil is Pennsylvania grade, and the pool now covers an area of 4200 acres and contains approximately 160 oil wells.

LARGE WELLS

The largest oil well of the year, and probably the largest Clinton oil well ever completed in Ohio, was the Wittmer Oil and Gas Company's Johnson No. 1, in the fourth quarter of Falls township, Muskingum County. This well had an initial production of 550 bbl. and a depth of 3494 ft. The oil is Pennsylvania grade. Unfortunately, very little acreage has been proved, the offset and adjacent completions all being dry or small. The 270-bbl. Clinton well in Clayton township, Perry County, that has been mentioned was the Wehrle Adrian No. 1, sec. 4, which was 3395 ft. deep. The Preston Oil Company's Madden No. 4, sec. 12, Reading township, Perry County, had an initial production of 243 bbl. from the Clinton at 3156 feet.

The year's largest gas well was the Ohio Fuel Gas Company's Sletzer No. 1, sec. 2, Wayne township, Muskingum County. The initial open flow was 14,000 M cu. ft. and the initial pressure 1160 lb. The well is 4031 ft. deep. Two additional large wells were in Lorain County, the larger being in lot 9, Penfield township, and having an open flow slightly under 13,000 M cu. ft., and the other in Wellington township, gauging 12,470 M cu. ft. Both produce from the Clinton sand at a depth of about 2400 feet.

In southern Ohio an outstanding Clinton gas well was found in northwestern Greenfield township, Gallia County—the Trenton Gas Company's Litton No. 1, sec. 18, with a depth of 2927 ft., an open flow of 7500 M cu. ft. and an initial pressure of 1030 pounds.

Deep Tests

An interesting test was made by Sinclair-Prairie in sec. 22, Olive township, Meigs County. It was drilled as an Oriskany test, but when that formation was unproductive was continued to the Clinton, and finally to the Trenton. This well has been briefly described under the section Horizons Tested.

Of the two deep and unproductive Clinton wells that have been mentioned, one was in sec. 2, Center township, Guernsey County, and ended at 5476 ft.; the other was in sec. 21, Wheeling township, Guernsey County, and ended at 4766 ft. In sec. 34, Union township, Tuscarawas County, a dry Clinton well was drilled to a depth of 5400 ft., and in lots 8 and 21, Mill township, Tuscarawas County, dry Clinton tests were drilled to depths of 5254 and 5218 ft., respectively. A deep test to the Clinton in sec. 6, Bristol township, Morgan County, was drilled to a depth of 4846 ft., where it was dry and abandoned. The deepest Clinton well of the year was that in sec. 16, Springfield township, Mahoning County, which finished at a depth of 6059 and was dry.

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Oil and Gas Development in Oklahoma in 1943

BY RAYMOND D. SLOAN,* MEMBER A.I.M.E.

DROPPING from third position among the oil-producing states of the nation in 1942, Oklahoma ranked fourth in 1943 with a total output of 121,431,000 bbl., a decline of 11.9 per cent from the previous year's total of 137,792,000 bbl.

Production ranged from a maximum of 346,900 bbl. daily in February to a low of 322,800 bbl. daily in October, and at the close of the year was averaging 330,000 bbl. daily from 52,096 wells, or an average of 6.3 bbl. per well. The state's well average at the close of 1942 amounted to 6.7 bbl. At the turn of the year, it appeared reasonable to assume that Oklahoma's producing rate would continue its downward trend during 1944 unless reversed by greater than normal discoveries. To Jan. 1, 1944, Oklahoma has produced 5,188,466,000 bbl. of crude oil.

DEVELOPMENT AND EXPLORATION

A total of 1287 wells was drilled in 1943, representing an increase of 77 wells, or 6.4 per cent over the preceding year's total of 1210. Of the wells completed, 587 (45.6 per cent) were oil wells with an average initial production of 319 bbl.; 127 (9.9 per cent) were gas wells with an average initial of 8,639,000 cu. ft.; and 573 (44.5 per cent) were dry.

A total of 333 wildcats was drilled (25.9 per cent of all wells), an increase of 13 (4.1 per cent) over the 1942 total of 320. Of the wildcats drilled, 46 (13.8 per cent) were oil wells with an average initial production of 235 bbl.; 27 (8.1 per cent) were gas wells with an average initial of 8,249,000 cu. ft.; and 260 (78.1 per cent) were recorded as failures. Reconditioning of wells throughout the state led to a total recompletion of 230 wells. Of these, 131 were oil wells with a combined initial production of 8360 bbl., 31 were gas wells with a total initial of 211,950,000 cu. ft., and 68 were abandoned.

The 46 successful wildcats opened 33 new producing areas, one of which produced from three separate horizons, and led to the development of production in new horizons in 11 old pools. While none of the 1943 discoveries have as yet developed into what might be termed major pools, the West Moore pool, in Cleveland County, and the West Edmond pool, in Oklahoma County, are the two outstanding new areas opened to production.

The West Moore pool, sec. 29, 10 N., 3 W., discovered in December 1943, was completed for an initial production of 248 bbl. of oil in 3 hr. through small tubing chokes in the second Wilcox sand from 8787 to 8800 ft. One well was drilling in this area at the close of the year. The West Edmond pool, an April discovery in sec. 32, 14 N. 4 W., is producing from the Hunton lime at a depth of approximately 6950 ft., the world's deepest Hunton lime pool. To the end of the year, 15 oil wells had been completed, with no gas wells and no failures. Accumulated production to Jan. 1, 1944, amounted to 474,300 bbl. of 41° gravity oil. There were 29 active operations in the field at the end of the year.

The West Edmond and West Moore pool discoveries established the first commercial production west of the Granite Ridge,

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* The Carter Oil Co., Tulsa, Oklahoma.

TABLE 1.—*Oil and Gas Development in Oklahoma.*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1943	
							During 1943		End of 1943			Number of Wells	
			Oil	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
	CENTRAL OKLAHOMA												
1	Agra, West, *Lincoln*	1927	40	223,633	29,513		1			3			3
2	Avery, *Lincoln*	1939	120	13,084	2,526					3			3
3	Chandler, *Lincoln*	1924	1,255	12,332,434	204,862		5			46			46
4	Davenport, *Lincoln*	1924	2,335	12,288,334	158,958	222				114			114
5	North, *Lincoln*	1941	130	62,332	8,666					5			5
6	West, *Lincoln*	1940	50	125,230	26,413					5			5
7	Gessman, *Lincoln*	1934	160	429,067	21,300					9			9
8	Hoyt, *Lincoln*	1935	265	1,395,785	34,595					8			8
9	Kendrick, *Lincoln*	1940	40	51,777	7,979		1			2			2
10	Laffoon, *Lincoln*	1932	470	2,260,800	186,675					12			12
11	Lincreek, *Lincoln*	1932	275	251,317	9,125					8			8
12	McLoud, North, *Lincoln*	1943	160	35,616	35,616	4	4			3			3
13	Meeker, South, *Lincoln*	1943	80	5,548	5,548	1	1			1			1
14	Payson, *Lincoln*	1940	40	15,815	3,975					1			1
15	Peck, *Lincoln*	1926	160	576,635	56,971					5			5
16	Perkins, *Lincoln*	1940	150	228,001	30,765					3			3
17	Sac and Fox, *Lincoln*	1924–37	1,830	3,509,031	183,142					140			140
18	Skellyville, *Lincoln*	1925	310	1,815,627	20,810					12			12
19	Sporn, *Lincoln*	1936	150	767,622	46,039					6			6
20	East, *Lincoln*	1942	10	7,650	5,609					1			1
21	Stroud, *Lincoln*	1923	590	9,222,652	155,654					25			25
22	Wellston, North, *Lincoln*	1936	500	1,479,606	49,458					9			9
23	Wilzetta, *Lincoln*	1934	220	1,190,638	48,687					11			11
24	South, *Lincoln*	1936–42	80	333,540	123,541		2			6			6
25	Miscellaneous, *Lincoln*		280	751,271	21,997					7			7
26	Cleveland, *Pawnee*	1904	4,255	40,436,910	140,890		4			214			214
27	Greenup, *Pawnee*	1926		*x*		Abandoned							
28	Hallet, *Pawnee*	1922	1,665	*x*	24,090		2			45			45
29	Jennings, *Pawnee*	1916	1,375	4,097,427	57,670					71			71
30	Keystone, *Pawnee*	1919	5,565	2,763,244	128,115					222			222
31	Lauderdale, *Pawnee*	1915	4,300	13,784,445	181,770					183			183
32	Maramec, *Pawnee*	1920	1,990	3,259,827	141,620					81			81
33	Masham, *Pawnee*	1924	290	*x*	6,570					5			5
34	Pawnee, East, *Pawnee*	1941	10	8,731		Abandoned							
35	Ralston, *Pawnee*	1924	205	*x*		Abandoned during 1943							
36	Skedee, *Pawnee*	1926	160	223,486	13,610		3			7			7
37	Terlton, *Pawnee*	1912	980	909,906	8,760					12			12
38	North, *Pawnee*	1917	2,010	3,261,667	42,705					69			69
39	Watchorn, *Pawnee*	1922	530	7,646,573	74,595					15			15
40	East, *Pawnee*	1942	820	1,456,465	1,025,333	22	7			22			22
41	Miscellaneous, *Pawnee*		280	*x*	13,020					8			8
42	Broyles, *Payne*	1918–39	170	*x*	12,045					5			5
43	East, *Payne*	1940	110	34,422		Abandoned							
44	Coyle, *Payne*	1938–40	1,338	5,795,693	1,614,026					36			36
45	North, *Payne*	1942	80	40,393	15,944					1			1
46	Garr, *Payne*	1920	1,135	2,742,538	128,845					32			32
47	Glencoe, *Payne*	1943	40	18,875	18,875	1	1			1			1
48	Ingalls, *Payne*	1914	1,110	6,325,089	105,850					30			24
49	Ingalls, East, *Payne*	1943	120	14,474	14,474	1	1			1			1
50	March, *Payne*	1922	1,410	*x*	62,415					20			20
51	North, *Payne*	1926	155	*x*	21,170					7			7
52	Markham, *Payne*	1928	260	64,700	6,203		1			4			4
53	West, *Payne*	1943	40	13,030	13,030	2	2			2			2
54	Mehan, *Payne*	Prior to 1925	670	2,339,218	1,372					3			3
55	Northeast, *Payne*	1941	85	92,073	29,616					3			3

[b] Footnotes to column heads and explanation of symbols are given on page 270.

TABLE I.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
			CENTRAL OKLAHOMA									
1												
2		44	Prue	Pen								
3		38	Various	Pen, Ord	S, L	Por	3,250	5,020		A		
4		43	Various	Pen	S	Por	2,600	3,580	50	ML		
5		41	Prue	Pen			3,535	3,548	13			
6		46	Prue	Pen								
7		44	Cleveland	Pen	S	Por	x	x		M		
8		40	1st Wilcox	Ord	S	Por	x	5,100	x			
9		50	Prue	Pen								
10		21	Wilcox	Ord	S	Por	4,190	4,275		A	Wilcox	
11		46	Wilcox	Ord	S	Por	x	x				
12		37	Wilcox	Ord	S		5,635	5,641	6		Wilcox	5,638
13		43	Wilcox	Ord	S		5,544	5,547	3		Wilcox	5,545
14		35	Lower Skinner	Pen								
15		23	2nd Wilcox	Ord								
16		43	Hunton	Sil								
17		46	Prue	Pen	S							
18		41	Various	Pen, Sil, Ord, Cam	S, L							
19		46	Simpson	Ord	S		4,500	4,600	x			
20			Upper Simpson, Wilcox	Ord	S		4,555		10			
21		41	Various	Pen, Ord	S	x	4,240	4,290	50		Wilcox	4,520
22		40	Wilcox	Ord	S							
23		40	Hunton, Viola	Sil-Dev, Ord								
24		35	Hunton, Viola, Bartlesville	Sil-Dev, Ord, Pen								
25		40	Prue, Wilcox	Pen, Ord	S							
26		36	Various	Pen, Ord, Cam	S, L	Por	1,300	2,400				
27												
28		38	Various	Pen, Ord								
29		37	Various	Pen, Mis, Ord	S, L	x	x	x				
30		37	Various	Pen, Mis, Ord	S, L		1,100	1,970				
31		37	Various	Pen, Ord, Cam	S, L		1,185	3,000				
32		37	Various	Pen			2,400	3,200				
33		39	Various	Pen, Mis, Ord	S, L							
34		42	Misener	Mis			3,363	3,367	4			
35		39	Various	Pen, Ord								
36		40	Bartlesville, Burgess, Skinner	Pen	S							
37		38	Various	Pen, Ord								
38		38	Various	Pen, Ord				x	x			
39		41	Various	Pen, Mis, Ord	S, L	Por						
40		43	Wilcox	Ord	S		3,880		15			
41		37	Bartlesville, Wilcox	Pen, Ord	S							
42		43	Bartlesville, Viola, Wilcox	Pen, Ord	S, L							
43		36										
44		46	Hunton, Wilcox	Sil, Ord	S, L	x	x	x	x			
45		41	Hunton	Sil-Dev	L		4,751		9			
46		38	Various	Pen, Mis, Ord	S, L							
47		43	Misener	Mis	S		4,029	48	19		Wilcox	4,121
48		39	Various	Pen, Mis, Ord	S, L		3,115	3,760				
49		45	Misener	Mis	S		3,750	3,756	6		Viola	3,776
50		38	Various	Pen, Ord								
51		43	Wilcox	Ord	S							
52		43	Burgess Sd-Miss Ls	Pen-Mis	S, L		3,266		13			
53		42	Wilcox	Ord	S		3,584	3,586	2		Wilcox	3,585
54		43	Various	Pen, Mis, Sil-Dev, Ord								
55		38	1st and 2nd Wilcox	Ord			4,065 4,100	4,076 4,103	11 3			

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b] Oil	Total Oil Production, Bbl. To End of 1943	Total Oil Production, Bbl. During 1943	Number of Oil and/or Gas Wells Completed to End of 1943	During 1943 Completed	During 1943 Abandoned	End of 1943 Temporarily Shut Down	End of 1943 Producing Oil[c]	End of 1943 Producing Gas[c]	Oil-production Methods, End of 1943, Number of Wells Flowing	Artificial Lift
56	New Cushing, *Payne*	1916	185	*x*		Abandoned							
57	Norfolk, *Payne*	1916	785	*x*	32,120					20			20
58	West, *Payne*	1929	390	*x*	60,225					22			22
59	Orlando, *Payne*	1929	210	1,027,633	25,242					1			1
60	East, *Payne*	1941	80	191,121	49,131					3			3
61	Ramsey, *Payne*	1938–40	630	8,174,667	1,585,863	42				41			41
62	Ripley, *Payne*	1923	375	*x*	14,600					5			5
63	North, *Payne*	1923	165	2,255,391	20,449		1			2			2
64	Stillwater, *Payne*	1935	130	535,714	7,843					3			3
65	West, *Payne*	1940	150	184,856	29,495					2			2
66	Yale-Quay, *Payne*	1914	4,095	23,258,552	584,365		1			160			160
67	Miscellaneous, *Payne*		160	*x*	4,508					3			3
68	Aggregate for district of pools marked *x*			5,829,999									
69	Total Central Oklahoma		48,213	186,160,164	7,794,878					1,806			
	EAST CENTRAL OKLAHOMA												
70	Hoffman, *McIntosh*	1917	300	*x*	1,460					2			2
71	Miscellaneous, *McIntosh*		10	85	43					1			1
72	Beland, *Muskogee*	1906	390	*x*	1,825					10			10
73	Boyle, *Muskogee*	1927	230	*x*	9,490					15			15
74	Boynton, *Muskogee*	1914	2,740	*x*	14,600					20			20
75	Butler, *Muskogee*	1918	1,500	*x*	21,900					60			60
76	Cole, *Muskogee*	1914	780	*x*	5,840					17			17
77	Council Hill, *Muskogee*	1919	335	*x*	24,090					30			30
78	Haskell, *Muskogee*	1909	1,750	*x*	25,915					77			77
79	Jolly-Patton, *Muskogee*	1920	260	*x*		Abandoned				19			19
80	Link, *Muskogee*	1909	715	*x*	44,895					32			32
81	Muskogee, *Muskogee*	1904	3,760	*x*	48,910					110			110
82	North, *Muskogee*	1906	290	*x*			Abandoned			22			22
83	Oktaha, *Muskogee*	1943	40	None	None	1	1			1			1
84	Robinson, *Muskogee*	1915	280	*x*			Abandoned			2			2
85	Sheppard, *Muskogee*	1917	140	*x*	2,190					1			1
86	Sommerville, *Muskogee*	1926		*x*			Abandoned						
87	Transcontinental, *Muskogee*	1918	215	*x*	2,190					7			7
88	Yahola, *Muskogee*	1914	680	*x*	5,110					18			18
89	Miscellaneous, *Muskogee*		820	*x*	8,395					10			10
90	Baltimore, North, *Okfuskee*	1922	525	*x*	4,015					5			5
91	Bearden, *Okfuskee*	1924		*x*			Abandoned						
92	Beidleman, *Okfuskee*	1930	100	276,991	5,363					6			6
93	Blakley, *Okfuskee*	1924	110	860,412	7,450					3			3
94	Cary, *Okfuskee*	1923	485	1,153,509	24,272					10			10
95	Clearview, *Okfuskee*	1927	240	*x*	17,155					10			10
96	Northwest, *Okfuskee*	1942	40	1,470	323					1			1
97	Cowan, *Okfuskee*	1940	80	33,552	7,862					2			2
98	Deaner, *Okfuskee*	1920	1,460	*x*	77,745					78			78
99	Fields, *Okfuskee*	1918	460	*x*	10,220					10			10
100	Gregory, *Okfuskee*	1922	390	*x*	18,250					15			15
101	Gypsy Hill, *Okfuskee*	1910	1,603	*x*	14,965					15			15
102	Haydenville, *Okfuskee*	1939	240	112,709	19,756					4			4
103	Josey, *Okfuskee*	1923	525	*x*	52,195					18			18
104	Keaton, *Okfuskee*	1919	210	*x*			Abandoned						
105	Lyons-Quinn, *Okfuskee*	1921	1,645	*x*	43,800					24			24
106	Mason, *Okfuskee*	1940	10	8,515			Abandoned						
107	Micawber, *Okfuskee*	1923	160	*x*	4,745					1			1
108	Midwest, *Okfuskee*	1942	80	76,282	49,853					4			4
109	Morgan, *Okfuskee*	1923	340	*x*	2,555					1			1
110	Okemah, *Okfuskee*	1921	1,050	*x*	79,935					50			50
111	East, *Okfuskee*	1940	160	365,301	71,516					7			7
112	North, *Okfuskee*	1941–42	160	181,463	83,207					11			11

TABLE I.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
56		38	Various	Pen, Ord								
57		38	Bartlesville, Wilcox	Pen, Ord	S							
58		38	Bartlesville, Wilcox	Pen, Ord	S							
59		41	Misener	Mis	S							
60		42	Misener	Mis	S		4,720	4,747	27			
61		43	1st Wilcox	Ord	S		4,768	4,795	27			
62		43	Various	Pen, Ord	S, L							
63		43	Wilcox	Ord	S	Por	x	x	x	x		
64		40	Wilcox	Ord	S	Por	4,300	4,306	6	A		
65		40	Hunton	Sil								
66		38	Oswego, Bartlesville, Wilcox	Pen, Ord	S, L		2,670	3,580				
67		39	1st and 2nd Wilcox	Ord								
68												
69												
EAST CENTRAL OKLAHOMA												
70		35	Wilcox	Ord	S							
71												
72		35	1st and 2nd Dutcher	Pen	S							
73		38	Dutcher	Pen	S							
74		35	Mississippian	Mis	L							
75		32	Unidentified sand									
76		35	Unidentified sand									
77		38	Various	Pen								
78		34	Tucker	Pen								
79		33	Muskogee, Timber-Ridge									
80		36	Booch, Dutcher	Pen								
81		38	Unidentified sand, Wilcox	Ord	S		1,052	1,790				
82		35	Wilcox	Ord	S							
83		42	Wainright		S		1,778	1,785	7		Wainright	1,785
84		39	Muskogee									
85		39	Unidentified sand									
86												
87		39	Booch	Pen	S							
88		39	Booch, Boynton	Pen								
89		38	Leidecher, Dutcher, Wilcox	Pen, Ord								
90		38	Dutcher, 1st and 2nd Wilcox	Pen, Ord								
91												
92		38	Wilcox	Ord	S							
93		39	Unidentified sand									
94		32	Various	Pen								
95		38	Wilcox	Ord	S							
96		39	Gilcrease	Pen	S		2,915		10			
97		42	Hunton	Sil-Dev								
98		38	Deaner, Lyons, Wilcox	Pen, Ord	S		2,800	3,650				
99		43	Deaner, Wilcox	Pen, Ord	S							
100		39	Various	Pen, Ord								
101		33	Youngstown, Dutcher, Wilcox	Pen, Ord	S		2,430	3,290				
102		31	Dutcher, Wilcox	Pen, Ord	S		3,600	3,650	50	D	Wilcox	3,700
103		40	Wilcox	Ord	S							
104		39	Dutcher, Quin	Pen								
105		39	Lyons	Pen								
106		39	Hunton	Sil-Dev								
107		36	Wheeler, Dutcher	Pen								
108		36	Hunton	Sil Dev	L		3,692		4			
109		37	Dutcher	Pen								
110		30	Gilcrease, Cromwell	Pen								
111		37	Lower Cromwell	Pen								
112		35	Gilcrease, Hunton	Pen, Sil-Dev								

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1943	
							During 1943		End of 1943			Number of Wells	
			Oil	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
113	Okemah, West, *Okfuskee*	1941	60	47,438	3,129					2			2
114	Okfuskee, *Okfuskee*	1938	100	135,062	9,115					5			5
115	Paden, *Okfuskee*	1914	80	*x*	4,380					3			3
116	Sheldon, *Okfuskee*	1916	900	*x*	28,835					15			15
117	Weleetka, *Okfuskee*	1913	1,815	*x*	167,535		4			73			73
118	South, *Okfuskee*	1937	90	61,227	2,059					3			3
119	West, *Okfuskee*	1926	250	942,524	75,312					15			15
120	Miscellaneous, *Okfuskee*		340	*x*	17,955					6			6
121	Aztec, *Okmulgee*	1917	2,140	*x*	49,275					49			49
122	Bald Hill, *Okmulgee*	1908	25,095	*x*	317,915					748			748
123	Beets-Rapp, *Okmulgee*	1920		*x*		Abandoned							
124	Beggs, North, *Okmulgee*	1909	1,840	*x*	13,505					19			19
125	Beggs, South, *Okmulgee*	1911	4,455	*x*	64,605					45			45
126	Brinton, *Okmulgee*	1914	545	*x*	13,140					15			15
127	Coalton, *Okmulgee*	1907	2,040	*x*	20,805		1			57			57
128	Edna, East, *Okmulgee*	1919	150	*x*	2,920					2			2
129	Eram, *Okmulgee*	1921	600	*x*	3,285					14			14
130	Gypsy Hill, Northwest, *Okmulgee*	1938	100	66,361	5,696					4			4
131	Hamilton Switch, *Okmulgee*	1909	2,570	*x*	25,550					71			71
132	Hector, *Okmulgee*	1914	645	*x*	1,460					7			7
133	Henryetta, *Okmulgee*	1910	785	*x*	8,760					33			33
134	Montezuma, *Okmulgee*	1918	220	*x*	5,110					4			4
135	Morris, *Okmulgee*	1907	7,300	*x*	104,025					209			209
136	Natura District, *Okmulgee*	1914	1,750	*x*	12,045					18			18
137	Nuyaka, South, *Okmulgee*	1937	105	518,678	15,453					6			6
138	Southwest, *Okmulgee*	1941	40	25,687	5,376					2			2
139	Oklahoma Central, *Okmulgee*	1921	545	*x*	10,220					8			8
140	Okmulgee, *Okmulgee*	1906	5,020	*x*	56,575					135			135
141	Phillipsville, *Okmulgee*	1920	580	*x*	5,475					7			7
142	Pine, *Okmulgee*	1915	815	*x*	6,205					26			26
143	Pollyanna, *Okmulgee*	1921	3,975	*x*	100,375		2			193			193
144	Schulter, *Okmulgee*	1907	455	*x*	4,015					9			9
145	Simmons-Black, *Okmulgee*	1920	455	*x*	24,455					12			12
146	Spencer, *Okmulgee*	1917	790	*x*	18,980					31			31
147	Summers, *Okmulgee*	1914	290	*x*	3,285					15			15
148	Tiger Flats, *Okmulgee*	1928	1,045	*x*		Abandoned							
149	Youngstown, *Okmulgee*	1915	2,235	*x*	21,900					43			43
150	Miscellaneous, *Okmulgee*		465	*x*	6,205					7			7
151	Airport, *Tulsa*	1937	330	143,456	1,500					13			13
152	Alsuma, *Tulsa*	1916	850	*x*	3,285					5			5
153	Bird Creek, *Tulsa*	1906	17,910	*x*	341,640					1,486			1,486
154	Bixby, *Tulsa*	1916	1,860	*x*	27,740					69			69
155	Broken Arrow, *Tulsa*	1901	3,665	*x*	21,535					55			55
156	Bruner Vern, *Tulsa*	1923	1,055	*x*	38,690					50			50
157	Collinsville, *Tulsa*	1916	120	*x*	3,650					10			10
158	Dawson, *Tulsa*	1906	765	*x*	10,220					40			40
159	Fisher, *Tulsa*	1918	685	*x*	4,380					7			7
160	Jenks, *Tulsa*	1901	6,885	*x*	75,555					298			298
161	Leonard, *Tulsa*	1916	1,000	*x*	17,155					32			32
162	Owasso, *Tulsa*	1913	360	*x*	5,475					13			13
163	Perryman, *Tulsa*	1924	345	*x*	1,460					10			10
164	Red Fork, *Tulsa*	1901	4,390	*x*	21,535					76			76
165	Sand Springs, *Tulsa*	1916	625	*x*	18,980					40			40
166	Tulsa, *Tulsa*	1901	910	*x*		Abandoned—1943							
167	Turkey Mountain, *Tulsa*	1922	1,115	*x*	27,375					47			47
168	Turley, *Tulsa*	1914	3,715	*x*	69,715					348			348
169	Wicey, *Tulsa*	1915	2,200	*x*	47,450					83			83
170	Bilby, *Wagoner*	1918	260	*x*	4,015					7			7

TABLE I.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
113		Dist.	Hunton	Sil-Dev			3,916	3,960	44			
114		39	Dutcher, Wilcox	Pen, Ord								
115		36	Prue	Pen	S							
116		42	Wilcox	Ord								
117		39	Gilcrease	Pen	S		2,530	2,660	130			
118		39	L. Gilcrease	Pen	S							
119		41	Booch	Pen	S							
120		36	Various	Pen, Ord								
121		38	Booch, Wilcox	Pen, Ord	S							
122		30	Glenn	Pen	S		750	2,250				
123												
124		38	Youngstown, Wilcox	Pen, Ord								
125		37	Various	Pen, Mis, Ord								
126		37	Wilcox	Ord	S							
127		30	Booch, Wilcox	Pen, Ord	S		1,300	2,835				
128		30	Unidentified sand									
129		40	Wilcox	Ord	S							
130		43	Wilcox	Ord	S		3,250		10			
131		29	Glenn, Dutcher, Wilcox	Pen, Ord	S		1,385	2,700				
132		37	Various	Pen, Mis, Ord	S, L							
133		38	Various	Pen, Sil-Dev, Ord, Cam	S, L							
134		38	Unidentified sand									
135		36	Various	Pen, Mis, Ord	S, L		1,600	2,450				
136		30	Various	Pen, Mis, Ord								
137		42	Wilcox	Ord	S							
138		38	Misener	Mis			3,168	3,176	8			
139		32	Wilcox	Ord	S							
140		30	Various	Pen, Mis, Ord	S		1,240	2,750				
141		45	Wilcox	Ord	S							
142		35	Booch, Dutcher	Pen	S							
143		34	Various	Pen, Ord, Cam	S, L		1,365	2,285				
144		36	Deaner, Glenn, Wilcox	Pen, Ord								
145		36	Salt, Booch	Pen								
146		33	Various	Pen, Mis, Ord, Cam								
147		38	Dutcher	Pen	S							
148		37	Various	Pen, Ord								
149		31	Youngstown	Pen	S							
150		40	Booch, Dutcher, Wilcox	Pen, Ord	S							
151		38	Bartlesville	Pen	S							
152		35	Burgess	Pen	S							
153		31	Bartlesville, Wilcox	Pen, Ord	S		1,110	1,345				
154		32	Various	Pen, Ord	S, L							
155		37	Various	Pen, Mis, Ord, Cam	S, L		1,350	1,500				
156		37	Various	Pen, Ord, Cam								
157		33	Various	Pen, Mis	S, L							
158		36	Bartlesville, Tucker	Pen	S							
159		34	Oswego, Tyner, Arbuckle	Pen, Ord, Cam								
160		36	Various	Pen, Mis Ord, Cam	S, L							
161		35	Various	Pen, Mis, Ord, Cam	S, L							
162		30	Various	Pen, Ord, Cam								
163		31	Unidentified sand				599	2,160				
164		34	Various	Pen, Ord, Cam								
165		37	Various	Pen, Ord, Cam								
166		34	Various	Pen, Mis, Ord								
167		35	Various	Pen, Ord, Cam	S, L		1,260	1,945				
168		32	Bartlesville, Burgess, Siliceous	Pen, Ord, Cam	S, L		1,480	1,950				
169		37	Various	Pen, Mis, Ord								
170		35	Dutcher, Burgess	Pen								

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres^b	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1943	
			Oil	To End of 1943	During 1943	Completed to End of 1943	During 1943		End of 1943			Number of Wells	
							Completed	Abandoned	Temporarily Shut Down	Producing Oil^c	Producing Gas^c	Flowing	Artificial Lift
171	Corine, *Wagoner*	1919	190	*x*	2,190					7			7
172	Coweta, *Wagoner*	1914	720	*x*	6,935					23			23
173	George, *Wagoner*	1918	270	*x*	8,395					32			32
174	Gillette, *Wagoner*	1924	65	*x*	1,095					8			8
175	Goble, *Wagoner*	1916	325	*x*	6,205					17			17
176	Johnson-Bailey, *Wagoner*	1920	80	*x*		Abandoned							
177	McCracken, *Wagoner*	1920	90	*x*	730					12			12
178	Oak Grove, *Wagoner*	1920	145	*x*		Abandoned—1943							
179	O.K., *Wagoner*	1919	80	*x*		Abandoned							
180	Oneta, *Wagoner*	1916	695	*x*	23,725					57			57
181	Seltzer, *Wagoner*	1924	65	*x*	1,825					11			11
182	Stone Bluff, *Wagoner*	1915	1,065	*x*	116,435					157			157
183	Striker, *Wagoner*	1917		*x*		Abandoned							
184	Wagoner, *Wagoner*	1914	460	*x*	43					43			43
185	South, *Wagoner*	1939	80	9,727	701					4			4
186	Webster, *Wagoner*	1917	60	*x*	1,460					11			11
187	Wright, *Wagoner*		80	*x*	242					1			1
188	Miscellaneous, *Wagoner*		170	*x*	3,283					7			7
189	Aggregate for district of pools marked *x*			310,404,666									
190	Total East Central		149,678	315,425,115	2,961,589					5,719			
	EAST CENTRAL (CREEK COUNTY)												
191	Arno	1923	210	*x*	39,420					14			14
192	West	1940	227	136,862	31,162					6			6
193	Bellview, *South*	1941	50	82,911	33,016					6			6
194	Big Pond	1924	470	*x*	120,815					32			32
195	Bowden	1906	3,495	*x*	117,165					211			211
196	Bristow	1916	5,255	*x*	278,860					127			127
197	North	1922	1,700	*x*	104,025					94			94
198	West	1922	565	*x*	18,615					10			10
199	Bruce	1926	515	*x*	33,215					39			39
200	Bruce, East	1939	100	*x*	6,205					8			8
201	Cushing	1912	24,940	365,416,701	2,988,985	3,696				1,716			1,716
202	Deep Fork	1920	3,345	*x*	124,100		5			120			120
203	Depew	1915	1,365	*x*	341,275					71			71
204	Donnelly	1924	730	*x*	79,205					33			33
205	Edna	1940	90	100,499	17,612					5			5
206	Glenn pool	1905	15,970	223,814,229	1,739,225		35			1,776			1,776
207	Hickory Grove	1942	220	68,542	29,609		3			14			14
208	Independent	1908	1,320	*x*	37,960					30			30
209	Iron Post	1917	925	*x*	24,820					55			55
210	Kellyville	1934	3,600	*x*	133,590					177			177
211	Mannford (deep and shallow)	1922–37	4,650	*x*	235,790					220			220
212	Mercer	1923	80	302,824	9,053					4			4
213	Milfay	1941	640	78,122	32,680					2			2
214	Mounds	1915	1,580	*x*	23,725					33			33
215	Newby	1929	80	*x*	4,015					4			4

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
171		39	Unidentified sand									
172		38	Various	Pen, Mis, Ord, Cam	S, L		700	1,280				
173		36	Dutcher	Pen	S							
174		38	Tyner	Ord								
175		37	Dutcher	Pen	S							
176		33	Unidentified sand									
177		43	Tyner	Ord								
178		33	Pitkin, Burgen	Pen, Ord								
179		36	Dutcher, Tyner, Burgen	Pen, Ord								
180		38	Dutcher, Mississippi, Tyner	Pen, Mis, Ord	S, L		1,000	1,200				
181		37	Dutcher	Pen	S							
182		36	Various	Pen, Mis, Ord, Cam			1,840	2,275				
183			Dutcher, Morrow-Pitkin	Pen, Mis								
184		35	Peru, Ordivician	Pen, Ord								
185		36	Pennsylvanian									
186		33	Burgen	Ord								
187		39	Pitkin	Pen	L							
188		32	Unidentified sand and lime									
189												
190												
			EAST CENTRAL (CREEK COUNTY)									
191		36	Simpson	Ord								
192		40	Prue, Red Fork, Bartlesville, Wilcox	Pen, Ord								
193		36	Red Fork Sd	Pen	S		2,756		10			
194		32	Jones, Glenn, Dutcher, Wilcox	Pen, Ord	S							
195		32	Taneha	Pen								
196		35	Layton, Ft. Scott, Oswego, Red Fork, Bartlesville, Dutcher, Miss., Wilcox	Pen, Mis, Ord	S, L		2,700	3,200				
197		35	Layton, Ft. Scott, Oswego, Red Fork, Bartlesville, Dutcher, Miss., Wilcox	Pen, Mis, Ord	S, L							
198		35	Dutcher	Pen			3,152	3,155				
199		35	Layton, Ft. Scott, Oswego, Red Fork, Bartlesville, Dutcher, Miss., Wilcox	Pen, Mis, Ord								
200		37	Layton	Pen								
201		39	Various	Pen, Ord	S, L	Por			x	AF		
202		42	Layton, Peru, Prue, Dutcher	Pen								
203		32	Glenn, Dutcher, Wilcox	Pen, Ord	S		2,700	3,397				
204		37	Dutcher, 1st Wilcox	Pen, Ord								
205		35	Wilcox	Ord								
206	RP	34	Various	Pen, Ord								
207		48	Bartlesville	Pen	S		3,119		11			
208		35	Taneha, Wilcox	Pen, Ord	S		2,100	2,550				
209		36	Wheeler, Prue, Cleveland	Pen	S		2,420	2,475				
210		30	Peru	Pen	S							
211		34	Various	Pen, Ord	S, L		1,550	2,980				
212		41	Dutcher, Wilcox	Pen, Ord	S							
213		35	1st & 2nd Wilcox	Ord	S		3,970		5			
214		33	Red Fork, Glenn, Tucker, Dutcher, Wilcox	Pen, Ord	S		400	2,400				
215		34	Dutcher	Pen	S							

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1943	
							During 1943		End of 1943			Number of Wells	
			Oil	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
216	Olean	1921	340	*x*	25,915					18			18
217	Olive	1914	2,235	*x*	110,230					179			179
218	South	1940	20	2,338	155					1			1
219	Pickett-Prairie	1916	1,820	*x*	8,395		1			56			56
220	Poor Farm	1920	340	*x*	13,870					13			13
221	Red Bank	1918	370	*x*	21,535					8			8
222	Sapulpa	1909	1,790	*x*	58,400					106			106
223	South	1910	2,570	*x*	79,205					70			70
224	Slick	1913	6,585	*x*	429,605		1			170			170
225	Stroud, East	1940	460	793,804	94,170					34			34
226	Southeast	1943	240	140,760	140,760	11	11			11			11
227	Tibbens	1924	430	*x*	19,345					36			36
228	North	1940	110	84,650	22,572					4			4
229	Tuskegee	1924	310	*x*	4,380					8			8
230	East	1925	540	1,222,060	112,193					31			31
231	Walker	1923	390	*x*	61,320					29			29
232	West	1939	80	121,987	11,562					7			7
233	Wilcox	1919	1,375	*x*	156,220					53			53
234	Miscellaneous		280	*x*	20,805					11			11
235	Aggregate for district of pools marked *x*			198,595,660									
236	Total East Central (Creek County)		92,407	790,961,949	7,994,779					5,652			
	NORTHEASTERN OKLAHOMA												
237	Craig, Nowata, Rogers, and Washington Counties		104,670	364,642,282	4,878,590					14,907			14,907
	NORTHERN OKLAHOMA												
238	Barnes, *Garfield*	1918	185	*x*	12,045					10			10
239	Brown, *Garfield*	1930	85	452,017	12,691					4			4
240	Enid, *Garfield*	1940	240	77,337	21,157		1			3			3
241	Garber, *Garfield*	1916	4,520	56,359,090	601,193	987				526			526
242	North, *Garfield*	1927	90	*x*	14,965					6			6
243	Hillsdale, *Garfield*	1938	160	103,726	7,321					1			1
244	Waukomis, *Garfield*	1938	1,040	35,044		Abandoned							
245	Miscellaneous, *Garfield*	1926	40	67,347	2,628					1			1
246	Caldwell, *Grant*	1929	80	269,325		Abandoned—1943							
247	Deer Creek, *Grant*	1922	210	1,365,157	33,580					10			10
248	Lamont, *Grant*	1937	60	788,843	7,148	Abandoned—1943							
249	Webb, *Grant*	1926	120	236,527	13,304					7			7
250	Blackwell, *Kay*	1918	1,750	5,429,356	131,506					40			40
251	Braman, *Kay*	1924	335	4,772,933	52,925	154				23			23
252	North, *Kay*	1924	795	18,634,537	186,515					45			45
253	Southeast, *Kay*	1938	440	460,179	57,037					4			4
254	Dilworth, *Kay*	1917	2,355	5,801,239	248,930					77			77
255	Hubbard, *Kay*	1924	645	8,656,053	134,685					33			33
256	Mervine, *Kay*	1913	960	*x*	12,045					2			2
257	Newkirk, *Kay*	1919	250	*x*	22,995					6			6
258	Ponca City, *Kay*	1917	1,445	6,575,394	77,015					40			40
259	Thomas, *Kay*	Prior to 1914	275	7,338,209	71,408					13			13
260	Tonkawa, *Kay*	1921	3,695	122,466,224	504,201	931				148			148
261	South, *Kay*	1921		*x*		Abandoned							
262	Vernon, *Kay*	1925	660	3,610,713	148,190		7			26			26
263	Miscellaneous, *Kay*		290	*x*	9,070					5			5
264	Crescent, *Logan*	1933	1,920	14,965,220	760,955	80	6			50			50

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
216		40	Layton, Peru, Wheeler, Skinner, Bartlesville	Pen	S							
217		36	Various	Pen	S							
218		38	Prue	Pen								
219		35	Glenn, Taneha, Wilcox	Pen, Ord								
220		34	Various	Pen								
221		36	Various	Pen, Ord								
222		34	Various	Pen, Mis, Ord	S, L		1,000	2,290				
223		36	Taneha, Dutcher, Wilcox	Pen, Ord								
224		32	Various	Pen, Mis, Ord			2,340	3,088			Wilcox	3,140
225		41	2nd Wilcox	Pen, Ord								
226		44	Prue	Pen	S		2,854	2,934	80		Prue	2,934
227		34	Various									
228		39	Wilcox	Ord								
229		38	Various	Pen, Ord								
230		39	Various	Pen, Mis, Ord								
231		35	Various	Pen, Mis, Ord	S, L							
232		37	Bartlesville	Pen	S							
233		35	Various	Pen, Ord								
234		39	Prue, Bartlesville, Wilcox	Pen, Ord	S							
235												
236												
Northeastern Oklahoma												
237		36										
Northern Oklahoma												
238		39	Tonkawa, Layton	Pen								
239		39	Wilcox	Ord	S							
240		40	Mississippian	Mis	L							
241		41	Various	Per, Pen, Ord	S, L	Por	1,100	4,200	*x*		*x*	*x*
242		44	Various	Pen, Ord								
243		39	1st and 2nd Wilcox	Ord	S		*x*	*x*			*x*	*x*
244		53	Marshall Zone		S	*x*	7,260	7,280	20		*x*	*x*
245		43	Wilcox	Ord	S	Por	*x*	*x*	6	A	*x*	*x*
246		40										
247		38	Various	Pen, Mis, Ord	S, L		2,900	4,175	*x*			
248		40	Wilcox	Ord	S	*x*	5,400	5,410	10		*x*	*x*
249		42	Various	Pen, Mis, Ord								
250		40	Various	Pen, Ord	S, L		1,600	3,440				
251		40	Various	Pen, Ord	S, L							
252		41	Various	Pen, Ord	S, L							
253		40	Arbuckle, Wilcox	Cam-Ord, Ord	S	*x*	*x*	*x*	*x*		*x*	*x*
254		40	Blackwell, Wilcox	Pen, Ord					*x*	A		
255		37	Various	Pen, Ord		Por	*x*	*x*	*x*	AF	*x*	*x*
256		39	Various	Pen								
257		40	Burbank, Mississippian	Pen, Mis								
258		38	Various	Pen, Mis, Ord	S, L		1,500	3,900		A		
259		41	Various	Per, Pen, Ord	S, L	Por			*x*	*x*		
260		42	Various	Pen, Mis, Ord	S, L	Por	2,660	4,075	*x*	*x*		
261			Endicott, Tonkawa, Wilcox	Pen, Ord								
262		40	Various	Pen, Mis, Ord	S, L				*x*	*x*		
263		39	Various							AF		
264		41	Layton, Wilcox, 2nd Wilcox	Pen, Ord	S	23						

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]: Oil	Total Oil Production, Bbl.: To End of 1943	Total Oil Production, Bbl.: During 1943	Number of Oil and/or Gas Wells: Completed to End of 1943	During 1943: Completed	During 1943: Abandoned	End of 1943: Temporarily Shut Down	End of 1943: Producing Oil[c]	End of 1943: Producing Gas[c]	Oil-production Methods, End of 1943, Number of Wells: Flowing	Artificial Lift
265	Crescent South, *Logan*	1942	40	25,694	17,108					2			2
266	Guthrie, *Logan*	1941	620	2,567,478	638,153					31			31
267	South, *Logan*	1943	80	1,848	1,848					1			1
268	Townsite, *Logan*	1942	400	125,035	81,670		1			2			2
269	Hull, *Logan*	1934	80	242,223	4,745					2			2
270	Langston, *Logan*	1934	340	1,817,141	137,721					14			14
271	South, *Logan*	1935	90	52,267	2,342					1			1
272	Lovell, *Logan*	1928	220	2,731,362	29,565		6			8			8
273	South, *Logan*	1934	200	567,073	144,165					8			8
274	West, *Logan*	1936		95,176		Abandoned							
275	Marshall, *Logan*	1927	740	11,878,870	52,560					21			21
276	Meridian, *Logan*	1938	240	177,483	8,011					3			3
277	Navina, *Logan*	1941	20	475	None					1			1
278	West, *Logan*	1942	320	236,523	89,106					8			8
279	Seward, *Logan*	1936	40	91,807	8,669					1			1
280	Billings: Deep, *Noble*	1935	750	15,022,838	1,689,711	79				73			73
281	Shallow, *Noble*	1917	590	6,218,495	8,966					7			7
282	Liberty, *Noble*	1942	120	230,660	112,416					3			3
283	East, *Noble*	1942	40	162,939	113,878					1			
284	Lucien, *Noble*	1932	4,170	31,151,862	1,250,855	130	1			120			120
285	North, *Noble*	1936	530	1,272,509	144,679					11			11
286	Northeast, *Noble*	1942	160	303,369	181,528					5			5
287	Marathon, *Noble*	1935	80	138,341		Abandoned							
288	Morrison "A," *Noble*	1942	40	950	950					1			1
289	Otoe City, *Noble*	1930	240	354,306	134,669		4			8			8
290	East, *Noble*	1943	200	28,503	28,503					4			4
291	Southeast, *Noble*	1943	10	724	724	1	1			1			1
292	Perry, *Noble*	1923	60	88,118	4,278					1			1
293	Southeast, *Noble*	1943	80	10,160	10,160	1	1			1			1
294	Polo, *Noble*	1934	510	4,497,288	186,901					25			25
295	Sams, *Noble*	1925	295	*x*	14,235		1			6			6
296	Northeast, *Noble*	1943	80	34,281	34,281	2	2			2			2
297	Aggregate for district of pools marked *x*			5,702,729									
298	Total Northern Oklahoma		34,030	344,292,997	8,275,906					1,452			
	OKLAHOMA CITY AREA												
299	Moore, *Cleveland*	1935	940	8,915,698	259,515	40				20			20
300	West, *Cleveland*	1943	880	9,612	9,612	1	1			1		1	
301	Noble, *Cleveland*	1938	30	74,489		Abandoned—1943							
302	Norman, *Cleveland*	1939	60	13,863	1,596					1			1
303	Stella, *Cleveland*	1943	40	21,848	21,848					1			
304	Britton, *Oklahoma*	1935	1,245	2,616,159	89,951					19			19
305	South, *Oklahoma*	1938	195	198,035	27,800					3			3
306	Edmond, *Oklahoma*	1930	1,000	20,019,487	940,654	104				77			77
307	Northeast, *Oklahoma*	1941	640	324,256	212,014		10			21			21
308	West, *Oklahoma*	1943	6,400	474,344	474,344	15	15			15			[1]
309	Jones, *Oklahoma*	1939	250	182,619	48,867					4			4
310	Luther, South, *Oklahoma*	1943	40	453	453	1	1			1			1
311	Newalla, *Oklahoma*	1934		3,247		Abandoned							
311*a*	South, *Oklahoma*	1939	80	24,137		Abandoned							
312	Nicoma Park, *Oklahoma*	1929	80	359,348	5,963					2			2
313	Oklahoma City, *Oklahoma*	1928	15,500	602,676,417	20,224,228	1,56	6			839			839
314	Miscellaneous, *Oklahoma*		80	27,660	14,164					2			2
315	Total Oklahoma City Area		27,460	635,941,672	22,331,009					1,006			

[1] Flowing and artificial lift, the exact number by each method being unknown.

TABLE I.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
265		43	Layton	Pen	S		5,237		26			
266		46	Bartlesville, 2nd Wilcox	Pen, Ord			5,109 5,425	5,123 5,445	14 20			
267			Skinner	Pen	S		5,683	5,697	14		Skinner	5,697
268		43	Dolomite, Wilcox	Ord	S		5,604		8			
269		40	Layton, Tonkawa, Wilcox	Pen, Ord	S	Por		4,800				
270		39	Wilcox	Ord	S	Por	5,100	5,145		A	Wilcox	5,190
271		40	Upper Simpson	Ord								
272		40	Tonkawa, Wilcox	Pen, Ord	S	*x*	*x*	*x*				
273		49	Layton	Pen								
274		40	2nd Wilcox	Ord	S	Por		*x*	*x*	*x*		
275		41	Tonkawa, Wilcox, L Simpson	Pen, Ord	S	*x*	*x*	*x*	*x*			
276		48	Wilcox	Ord	S	*x*	5,200	5,220	20			
277		37	1st Wilcox	Ord			6,220	6,250				
278		42	Layton	Pen	S		5,010		33			
279		38	Simpson dolomite	Ord	D							
280		41	Wilcox	Ord	S	Por	4,250	*x*	*x*	A		
281		41	Various	Pen	S, L	Por			50	A		
282		43	Tonkawa, Wilcox	Pen-Ord	S		2,374		10			
283		45	Wilcox	Ord	S		4,508		20			
284		42	Various	Pen, Ord	S, L	Por	*x*	5,200	*x*	*x*		
285		41	Wilcox	Ord	S	Por	*x*	*x*	*x*	*x*		
286		40	2nd Wilcox	Ord	S		5,389		10			
287		42	Wilcox	Ord	S	Por	*x*	*x*	34	A		
288			Miss Ls	Mis	L		4,050		10			
289		39	Layton, Wilcox	Pen, Ord	S	Por	3,284	3,314	30	*x*		
290			Tonkawa, Perry, Layton	Pen	S		2,562	2,750	188		Wilcox	4,669
291			Burgess		S		4,394	4,414	20		Wilcox	4,754
292		41	Tonkawa, Reagan	Pen, Ord								
293			Perry		S		3,494	3,501	7		Perry	3,501
294		41	Various	Pen, Ord	S	*x*	4,823	4,900	*x*	*x*		
295		42	Tonkawa	Pen	S		1,902	1,912	10			
296		46	Misener	Dev	S		5,050	5,064	14		Wilcox	5,251
297												
298												
Oklahoma City Area												
299		41	Dolomite, U. Simpson, 2nd Wilcox	Ord								
300			Wilcox, 2nd	Ord	S		8,787	8,800	3		2d Wilcox	8,800
301		39	2nd Wilcox	Ord	S		7,670	7,672	2			
302		38	Upper Simpson	Ord	*x*	*x*	*x*	*x*	*x*			
303			Dolomite	Ord			6,498	6,521	23		Wilcox	6,603
304		45	Simpson, 2nd Wilcox	Ord	S, D, L	Por				AF		
305		35	2nd Wilcox	Ord	S		6,738	6,766	28			
306		39	Simpson, Wilcox	Ord		Por				AF	Arbuckle	7,000
307		37	Red Fork	Pen	S		5,920		5			
308		41	Hunton		L		6,938	6,956	18		Wilcox	7,690
309		35	Cleveland	Pen	S	*x*	4,796	4,808	12		2nd Wilcox	5,998
310		37	Hunton		L		5,543	5,556	13		Wilcox	5,885
311			Hunton		L		6,045	6,079	34			
311*a*		35	Hunton	Sil-Dev	L		6,004	6,095	91		2nd Wilcox	6,610
312		36	Trosper	Pen	S	Por	6,157	6,168	11	ML		
313		37	Various	Pen, Ord	S, L	Por		6,700	*x*			
314												
315												

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1943	
							During 1943		End of 1943			Number of Wells	
			Oil	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
	OSAGE COUNTY												
316	Almeda	1918	1,205	*x*	5,840					69			69
317	Atlantic	1924	1,330	*x*	296,380					88			88
318	Avant	1904	12,520	*x*	773,800		1			756			756
319	West	1905	3,555	*x*	47,450					154			154
320	Backius	1919	850	*x*	9,125					32			32
321	Bandwheel	1921	630	*x*	32,120					40			40
322	Barker	1932	240	*x*	24,820					11			11
323	Barnsdall	1916	3,620	*x*	63,510					207			207
324	South	1921	1,125	*x*	23,360					85			85
325	West	1922	1,665	*x*	122,275					109			109
326	Bartlesville	1904	16,335	*x*	16,060					81			81
327	Big Bend	1943	320	104,705	104,705					4			4
328	Big Horse	1927	335	*x*	4,015					23			23
329	Birch Creek	1920	830	*x*	8,760					48			48
330	Boston	1904	770	*x*	102,565					32			32
331	West	1941	160	105,911	38,550					5			5
332	North	1921	240	*x*	14,600					9			9
333	Bowring	1921	160	*x*	2,555					12			12
334	Branstetter	1928	420	*x*	19,710					25			25
335	Buell	1922	100	*x*	7,300					9			9
336	Bulldog	1920	465	*x*	28,470					31			31
337	Burbank (*Osage and Kay*)	1920	24,665	211,770,387	3,249,772	2,205	1			1,690			1,690
338	South	Or. 1926 Ext. 1934	4,465	36,140,872	2,637,917	287				223			223
339	Candy Creek	1920	1,420	*x*	64,240					55			55
340	Canyon Creek	1923	160	*x*	54,020		1			7			7
341	Country Club	1923	515	*x*	22,265					30			30
342	Dalton	1926	205	*x*	2,555					3			3
343	Dewey	1904	4,920	*x*	18,615					108			108
344	Domes	1917	3,740	*x*	67,525					187			187
345	Edgewood	1921	285	*x*	3,285					3			3
346	Elgin, South	1917	1,985	*x*	18,980					107			107
347	Enfisco	1921	290		2,923					6			6
348	Fairfax	1925	220	*x*	18,615					16			16
349	Falls Dome	1920	380	*x*	16,060					19			19
350	Flat Rock	1906	7,485	*x*	236,885					578			578
351	Flesher	1919	320	*x*	4,745					5			5
352	Foraker (Redrilled)	1920-42	20	*x*	2,970					1			1
353	Forty-five	1916	1,795	*x*	28,835					107			107
354	Frankfort	1920		*x*		Abandoned							
355	Gilliland	1919	770	*x*	14,718					13			13
356	Happy Hollow	1919	540	*x*	43,435					27			27
357	Hardy	1934	40		8,584					2			2
358	Hickory Creek	1914	2,220	*x*	43,800					155			155

TABLE I.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
							Depth, Avg. Ft.					
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole, Ft.
				OSAGE COUNTY								
316		33	Bartlesville, Burgess, Mississippian	Pen, Mis								
317		39	Burgess, Siliceous	Mis, Ord, Cam	S, L		2,500 2,750	2,525 2,765	25 15			
318	RP	33	Bartlesville, Burgess	Pen	S		1,400 1,450	1,465 1,600				
319		32	Bartlesville, Burgess	Pen	S							
320		34	Bartlesville, Mississippian	Pen, Mis	S, L							
321		34	Various	Pen, Mis	S, L							
322		36	Various	Pen, Mis, Ord, Cam								
323		33	Peru, Bartlesville, Mississippian, Arbuckle	Pen, Mis, Cam	S, L		1,110 1,550	*x* 1,725	*x* 75			
324		33	Bartlesville, Burgess	Pen	S							
325		34	Bartlesville	Pen	S							
326		33	Various	Pen			650	1,265				
327		41	Layton	Pen	S		2,874	2,890	16		Layton	2,890
328		35	Bartlesville, Mississippian	Pen, Mis	S, L							
329		34	Bartlesville, Burgess, Mississippian	Pen, Mis	S, L							
330		37	Various	Pen, Mis, Ord, Cam	S, L		1,500	2,620				
331		38	Simpson	Ord	S		3,064		15			
332		36	Wilcox, Arbuckle	Ord, Cam								
333		34	Layton, Peru, Oswego, Mississippian	Pen, Mis	S, L							
334		40	Bartlesville, Burgess, Mississippian	Pen, Mis	S, L							
335		37	Various	Pen, Mis	S, L							
336		34	Various	Pen, Mis	S, L							
337	RP	38	Layton, Burbank, Wilcox	Pen, Ord	S		2,700	2,850	60	ML	Granite	4,240
338	PM	38	Burbank, Skinner	Pen	S			2,850				
339		33	Bartlesville, Burgess	Pen	S							
340		39	Bartlesville, Burgess	Pen	S							
341		33	Various	Pen, Ord								
342		38	Bartlesville, Burgess	Pen	S							
343		33	Various	Pen	L, S		650	1,265				
344		36	Stray, Bartlesville, Mississippian	Pen, Mis	S, L		1,570 1,680 1,880	1,124 1,780 1,925	67 100 45			
345		35	Bartlesville, Burgess, Mississippian	Pen, Mis	S, L							
346		33	Ramsey, Pennsylvanian, Oswego	Pen								
347		36	Stray, Oswego, Mississippian	Pen, Mis	S, L							
348		38	Oswego, Burbank, Wilcox	Pen, Ord	S	20–25			*x*	ML		
349		36	Oswego, Bartlesville, Burgess	Pen								
350	RP	34	Bartlesville, Burgess	Pen	S		1,110 1,345	1,205 1,365	95 20		Wilcox	1,667
351		35	Bartlesville, Mississippian	Pen, Mis								
352												
353		34	Oswego, Skinner, Bartlesville	Pen								
354			Pennsylvanian, Oswego, Mississippian	Pen, Mis	S, L							
355		36	Various	Pen, Mis, Ord, Cam	S, L							
356		36	Oswego, Bartlesville, Burgess	Pen								
357		39	Layton	Pen	S							
358		35	Oswego, Bartlesville, Mississippian	Pen, Mis	S, L							

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1943	
							During 1943		End of 1943			Number of Wells	
			Oil	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
359	Hickory Creek, South	1939	340	*x*	67,359					41			41
360	Hominy	1916	415	*x*	20,805					11			11
361	East	1918	630	*x*	16,790					20			20
362	South	1940	30	12,184	944					3			3
363	Hominy Falls	1919	1,385	*x*	27,375					52			52
364	Kasishke	1921	140	*x*	5,475					17			17
365	Kaw	1922	180		29,770					7			7
366	Landon	1919	145	*x*	1,825					9			9
367	Lee Dome	1926	80	*x*	5,840					5			5
368	Madalene	1920	520	*x*	20,075					38			38
369	East	1923	400	*x*	15,695					33			33
370	Manion	1927	460		19,421					31			31
371	North	1920	910	*x*	51,830					59			59
372	Myers	1919	260	*x*		Abandoned							
373	Naval Reserve	1933	3,290	18,701,968	832,119					233			233
374	Naval Reserve, South	1938	80	415,746	33,951					6			6
375	Nelagoney (Redrilled)	1919–42	80	*x*	15,695		1			4			4
376	New England	1920	585	*x*	25,550					27			27
377	Ochelata, North	1910	1,560	*x*	37,230					86			86
378	Ohio-Osage	1932	195	*x*	296					24			24
379	Okesa	1904	1,210	*x*	2,920					10			10
380	Osage City	1904	3,805	*x*	228,125					218			218
381	East	1920	805	*x*	46,720					61			61
382	Osage-Hominy	1917	1,625	*x*	239,440					138			138
383	Page	1918	745	*x*	20,805					29			29
384	Pawhuska	1919	505	*x*	26,280					18			18
385	West	1919	180	*x*	3,650					6			6
386	Pearsonia	1919	220	*x*	86,870					21			21
387	Penn Creek	1922	160	*x*	6,205					2			2
388	Pershing	1918	5,595	*x*	93,805					236			236
389	Pettit	1923	285	*x*	24,455					15			15
390	Pioneer	1920	300	*x*	15,695					21			21
391	Pond Creek	1913	1,295	*x*	16,060					56			56
392	Prue	1926	475	*x*	5,110					11			11
393	Quapaw	1914	3,645	*x*	56,575					194			194
394	Ramona	1911	1,755	*x*	73,365					81			81
395	Skiatook	1911	715	*x*	17,520					27			27
396	Sunset	1919	295	*x*	1,460					10			10
397	Tidal-Osage	1918	1,975	*x*	68,620					106			106
398	Turkey Creek	1917		*x*		Abandoned							
399	West	1925	305	*x*		Abandoned							
400	Whitetail	1919	205	*x*	2,190					1			1
401	Wildhorse	1912	4,670	*x*	225,935					389			389
402	North	1919	360	*x*	12,775					20			20
403	South	1923	205	*x*	11,315					11			11
404	West	1940	160	122,024	29,270					4			4
405	Woolaroc	1917	2,525	*x*	43,435					157			157
406	Wynona	1917	3,475	*x*	53,290					157			157
407	Miscellaneous		2,380	*x*	112,849					96			96
408	Aggregate for district of pools marked *x*			335,704,538									
409	Total Osage County		154,885	603,078,335	11,059,498					7,973			

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
359		36	Wayside									
360		34	Various	Pen, Mis, Ord, Cam	S, L		2,625	2,685	50	A	Arbuckle	3,206
361		34	Bartlesville, Mississippian, Hominy, Arbuckle	Pen, Mis, Ord, Cam	S		2,160	2,210		A	Arbuckle	2,857
362		40	Oswego	Pen								
363		36	Various	Pen, Mis	S, L							
364		40	Burbank	Pen	S							
365		35	Prue, Skinner	Pen								
366		35	Peru, Oswego, Bartlesville	Pen								
367		36	Oswego, Bartlesville, Burgess	Pen								
368		35	Prue, Oswego, Bartlesville	Pen								
369		35	Bartlesville	Pen	S							
370		38	Layton, Oswego, Bartlesville, Burgess	Pen								
371		38	Bartlesville, Wilcox	Pen, Ord	S							
372		34	Layton, Burgess	Pen								
373		39	Burbank	Pen	S				x	x		
374			Simpson (Hominy)	Ord	S		2,940	3,050	110			
375												
376		34	Bartlesville, Burgess, Arbuckle	Pen, Ord, Cam								
377		34	Prue, Bartlesville	Pen	S							
378		37	Cleveland, Bartlesville	Pen	S							
379		34	Prue, Bartlesville, Mississippian	Pen, Mis	S, L							
380		37	Burbank, Burgess, Arbuckle	Pen, Ord, Cam	S, L							
381		37	Cleveland, Bartlesville	Pen	S		1,620 2,250	1,645 2,280	25 30		Mississippian	2,431
382		37	Layton, Oswego, Bartlesville, Burgess	Pen	S, L		x	x	x			
383		33	Various	Pen, Ord, Cam	S, L							
384		35	Bartlesville, Burgess, Burgen, Arbuckle	Ord								
385		36	Bartlesville, Burgess, Burgen, Arbuckle	Pen, Ord, Cam	S, L							
386		36	Layton, Oswego, Burgess, Mississippian	Pen, Mis	S, L							
387		35	Bartlesville, Mississippian	Pen, Mis	S, L							
388		35	Cleveland, Bartlesville	Pen	S		1,385 2,033	1,400 2,063	15 30	D		
389		36	Various	Pen, Ord, Cam	S, L		x	x	45	A	2nd Wilcox	
390		34	Various	Pen, Ord	S, L							
391		33	Various	Pen, Mis	S, L							
392		36	Prue, Bartlesville	Pen	S							
393		34	Oswego, Skinner, Bartlesville	Pen	S		1,720	1,780	60			
394		33	Big Lime, Bartlesville, Burgess	Pen	S, L							
395		34	Bartlesville, Burgess, Mississippian	Pen, Mis	S, L							
396		36	Bartlesville, Hominy, Arbuckle	Pen, Ord	S, L							
397		36	Burgess, Bartlesville	Pen	S							
398												
399		33	Pennsylvanian sand	Pen	S							
400		32	Stray, Bartlesville, Mississippian	Pen, Mis	S, L							
401		35	Various	Pen, Ord	S, L		3,550	4,260				
402		35	Various	Pen, Ord	S, L							
403		35	Various	Pen								
404		38	Arbuckle	Ord, Cam								
405		34	Skinner, Bartlesville	Pen	S							
406		35	Various	Pen, Mis	S, L		1,600	2,281				
407		35										
408												
409												

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1943	
							During 1943		End of 1943			Number of Wells	
			Oil	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
	SEMINOLE AREA												
410	Adams, *Hughes*	1935	320	1,832,214	256,109					10			10
411	Alabama, *Hughes*	1923	640	*x*	21,900					20			20
412	Buchner, *Hughes*	1924	140	*x*	9,128					1			1
413	Calvin, *Hughes*	1938	80	105,088	3,053					3			3
414	Fish, *Hughes*	1934	1,870	18,745,276	698,134					140			140
415	Fuhrman, *Hughes*	1925	395	1,807,099	3,645					1			1
416	Gilcrease, *Hughes*	1924	245	422,120	645					1			1
417	Holdenville, North, *Hughes*	1926	80	141,357	1,859					1			1
418	West, *Hughes*	1916–30	1,380	5,648,018	170,557					107			107
419	Horns Corner, *Hughes*	1943	160	155,811	155,811	5	5			5			1
420	Jefferson, *Hughes*	1925		407,219		Abandoned							
421	Lamar, *Hughes*	1923		104,160		Abandoned							
422	Papoose, *Hughes*	1923	2,815	22,196,772	161,834	379				54			54
423	Spaulding, *Hughes*	1929	80	86,620	4,872					2			2
424	South, *Hughes*	1943	160	23,016	23,016					2			2
425	Southeast, *Hughes*	1939	40	26,104	9,593					4			4
426	Wetumka, *Hughes*	1923	255	*x*	14,969		1			4			4
427	East	1938	80	172,382	1,874					3			3
428	South	1926	100	*x*	3,533					4			4
429	Yeager, *Hughes*	1925	345	1,958,000	31,530					4			4
430	North, *Hughes*	1936	100	175,335	22,554					6			6
431	Miscellaneous, *Hughes*		180	156,659	5,861					8			8
432	Bearden, Northwest, *Okfuskee*	1941	100	184,592	119,614					12			12
433	Castle, *Okfuskee*	1941	200	167,189	38,194					2			2
434	North, *Okfuskee*	1941	200	61,623	16,626					4			4
435	South, *Okfuskee*	1941	120	33,680	5,142					3			3
436	Cromwell, East, *Okfuskee*	1940	540	4,218,144	844,488					72			72
437	North, *Okfuskee*	1938	Consolidated with "Cromwell, East"										
438	Dill, *Okfuskee*	1931	1,590	5,101,055	292,915		1			84			84
439	Northeast, *Okfuskee*	1943	120	131,935	131,935	11	11			11			1
440	Olympic, *Okfuskee*	1934	3,860	12,298,869	416,130	349	1			318			318
441	Rusk, *Okfuskee*	1941	300	1,132,367	447,122					10			10
442	Asher, *Pottawatomie*	1929	430	3,691,121	29,299					5			5
443	West, *Pottawatomie*	1930	780	7,653,563	87,215					31			31
444	Avoca, *Pottawatomie*	1938	220	1,429,431	96,998		2			17			17
445	Brooksville, *Pottawatomie*	1942	440	483,257	287,739		2			10			10
446	South, *Pottawatomie*	1943	100	25,221	25,221	1	1			1			1
447	Burnett, West, *Pottawatomie*	1943	200	2,303	2,303	1	1			1			1
448	Centerpoint, *Pottawatomie*	1942	200	98,926	52,478					5			5
449	Earlsboro, Northwest, *Pottawatomie*	1942	200	150,755	146,843					8			8
450	West, *Pottawatomie*	1924–29	1,405	3,654,568	420,795					74			74
451	Gray, *Pottawatomie*	1932	320	4,994,555	307,558					26			26
452	Grisso, *Pottawatomie*	1934	210	385,335	14,707					3			3
453	Hotulke, West, *Pottawatomie*	1941–42	1,000	1,441,889	379,750					22			22
454	King, *Pottawatomie*	1939	100	141,507	8,758					3			3
455	West, *Pottawatomie*	1939	100	231,717	1,131					1			1
456	Lake Shawnee, *Pottawatomie*	1943	40	23,097	23,097	1	1			1			1
457	Macomb, *Pottawatomie*	1942	300	49,522	22,211					3			3
458	South, *Pottawatomie*	1943	120	91,800	91,800	4	4			3			3
459	Maud, *Pottawatomie*	1928	1,980	12,423,848	158,011	158				56			56
460	South, *Pottawatomie*	1941	140	485,382	66,388					9			9
461	Prague, *Pottawatomie*	1940	220	1,001,485	190,177					17			17
462	Romulus, *Pottawatomie*	1940	450	1,408,129	170,287					18			18
463	Townsite, *Pottawatomie*	1942	80	35,707	17,191					1			1
464	Sacred Heart, *Pottawatomie*	1939	140	336,277	30,064					8			8

TABLE I.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
				SEMINOLE AREA								
410		40	Misener	Mis	S	Por			15	A	Wilcox	4,317
411		39	Various	Pen								
412		35	Booch, Cromwell	Pen	S		*x*	*x*	*x*			
413		36	Viola	Ord	L		*x*	*x*	*x*			
414		37	Various	Pen, Ord			*x*	*x*	*x*			
415		37	Gilcrease, Cromwell	Pen	S		*x*	*x*	*x*			
416		39	Gilcrease	Pen	S		*x*	*x*	*x*			
417		40	Cromwell	Pen	S		3,418	3,437	19			
418		37	Various	Pen, Ord	S							
419		37.3	Cromwell	Pen	S		3,865	3,683	18			
420												
421		39										
422		36	Calvin, Gilcrease, Cromwell	Pen	S	Por			10	A	Wilcox	
423		35	Booch	Pen	S							
424		33	Booch	Pen	S		2,635	2,658	23			
425		36	Booch	Pen	S		2,648	2,670	22			
426		38	Various	Pen, Sil-Dev	S, L							
427		53	Hunton, 2nd Wilcox	Sil-Dev, Ord	S							
428		39	Gilcrease, Cromwell	Pen	S							
429		39	Various	Pen, Sil-Dev, Ord	S, L							
430		37	Cromwell, Hunton, 2nd Wilcox	Pen, Sil-Dev, Ord	S, L							
431		35	Booch, Cromwell	Pen	S							
432		36	Booch	Pen	S		2,954		20			
433		43	Booch, Hunton	Pen, Sil-Dev			3,950	3,960				
434		41	Cromwell	Pen			3,310	3,323	13			
435		43	Hunton	Sil-Dev			3,930	3,942	12			
436		36	Cromwell, Hunton, Wilcox	Pen, Sil-Dev, Ord								
437		36	Booch, Cromwell	Pen	S							
438		36	Senora, Cromwell, Hunton	Pen, Sil-Dev	S, L	Por						
439		37	Cromwell	Pen	S		3,488	3,505	17			
440		34	Senora, Cromwell	Pen	S	Por	3,433	3,475	*x*			
441		38	Cromwell	Pen			3,691	3,710				
442		39	Wanette, Viola	Ord	S, L		*x*	*x*	*x*			
443		43	Wanette				3,450					
444		39	Viola, 2nd Wilcox	Ord	S, L							
445		33	Hunton	Sil-Dev	L		4,759		28			
446		33	Hunton	Sil-Dev	L		4,854	4,870	16		2nd Wilcox	5,481
447			2nd Wilcox	Ord	S		6,241	6,251	10		2nd Wilcox	6,251
448		40	Dolomite	Ord	S		5,593		20			
449		37	Earlsboro	Pen	S		3,875		20			
450		38	Hunton	Sil-Dev	L		*x*	*x*	*x*			
451		40	Wanette, Hunton, Simpson	Sil-Dev, Ord			2,500	3,475	25	A	Wilcox	3,500
452		36	Hunton, Simpson	Sil-Dev, Ord	L						Wilcox	4,860
453		38	Viola, Wilcox, Hunton	Ord, Sil-Dev	S, L							
454		41	Hunton, Viola	Sil-Dev, Ord	L		4,374	4,416	42			
455		41	Hunton	Sil-Dev	L		4,281	4,306	25			
456		40	Wilcox	Ord	S		5,877	5,885	8			
457		34	Hunton	Sil-Dev	L		4,700		75			
458		35	Hunton	Sil-Dev	L		4,664	4,760	96		2nd Wilcox	5,451
459		38	Misener, Hunton, Simpson	Mis, Sil-Dev, Ord	S, L	Por	4,130	4,140	10	A	Wilcox	4,330
460		40	Simpson	Ord	D		4,320	4,325	5			
461		34	Senora	Pen								
462		38	Hunton	Sil-Dev								
463		28.	Hunton	Sil-Dev	L		4,880		20			
464		32	Earlsboro	Pen	S		2,862	2,883	21			

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1943	
							During 1943		End of 1943			Number of Wells	
			Oil	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
465	Shawnee, *Pottawatomie*	1934	700	3,366,241	233,539					48			48
466	East, *Pottawatomie*	1937	40	65,567		Abandoned							
467	North, *Pottawatomie*	1937	90	494,500	102,386					4			4
468	Northeast, *Pottawatomie*	1942	70	219,487	209,645		3			4			
469	South, *Pottawatomie*	1943	20	16,823	16,823					2			2
470	Southwest, *Pottawatomie*	1943	40	2,087	2,087	1	1			1			1
471	St. Louis, *Pottawatomie*	1927	19,905	163,050,650	3,589,809	1,225	2			746			746
472	East, *Pottawatomie*	1941	110	212,768	33,347					8			8
473	North, *Pottawatomie*	1941	1,000	1,037,503	192,777					30			30
474	Tecumseh, *Pottawatomie*	1937	40	172,074	14,540					1			1
475	East, *Pottawatomie*	1941	280	431,646	32,481					9			9
476	Tecumseh Lake, *Pottawatomie*	1941	150	1,079,664	138,109		1			10			10
477	Wanette, *Pottawatomie*	1943	40	18,011	18,011					1			1
478	West, *Pottawatomie*	1943	10	3,070	3,070					1			1
479	Miscellaneous, *Pottawatomie*		150	*x*	6,161					5			5
480	Allen (deep), *Seminole*	1927	3,400	53,929,825	1,239,755	474	1			293			293
481	Bethel, *Seminole*	1925	620	1,928,156	54,054					35			35
482	North, *Seminole*	1936	300	4,291,287	215,820					26			26
483	Northeast, *Seminole*	1941	20	11,173	4,507					3			3
484	West, *Seminole*	1941	150	336,518	136,925					5			5
485	Bowlegs, *Seminole*	1926	4,000	122,732,500	1,713,892	364				203			203
486	Carr City, *Seminole*	1927	1,885	32,050,952	598,872	122				72			72
487	Cromwell, *Seminole*	1923	5,465	58,964,624	883,555	503	1			230			230
488	South, *Seminole*	1937	100	571,606	46,700					5			5
489	Dill, South, *Seminole*	1941	100	173,446	34,111					4			4
490	Dora, *Seminole*	1935	1,110	5,250,021	245,515					102			102
491	Earlsboro, *Seminole*	1926–42	5,235	127,587,971	995,313	499				164			164
492	East, *Seminole*	1929	2,105	39,720,770	483,522	192				74			74
493	North, *Seminole*	1936	460	7,196,002	983,715					36			36
494	South, *Seminole*	1930	430	9,342,942	193,643	39				26			26
495	Fish, West, *Seminole*	1941	30	20,597	5,855					1			1
496	Grayson, *Seminole*	1935	530	2,215,155	153,269		1			32			32
497	North, *Seminole*	1942	80	4,739	1,187					1			1
498	Hazel, *Seminole*	1938	330	539,682	59,786					17			17
499	Jackson, *Seminole*	1925	735	790,800	26,388					12			12
500	Keokuk, *Seminole*	1933	2,585	13,281,204	680,960	108	1			88			88
501	Konawa, *Seminole*	1929	1,695	15,838,611	307,729	133				92			92
502	East, *Seminole*	1936	225	222,495	9,666					5			5
503	South, *Seminole*	1938	560	1,382,386	141,443					44			44
504	West, *Seminole*	1938	220	707,555	64,971					15			15
505	Little River, *Seminole*	1927	4,090	115,144,604	1,549,548	602				212			212
506	East, *Seminole*	1928	910	17,065,119	165,056					62			62
507	North, *Seminole*	1941	220	422,545	126,027					5			5
508	Southeast, *Seminole*	1940	40	32,421	9,637					2			2
509	West, *Seminole*	1938	220	1,022,579	84,793					13			13
510	Mission, *Seminole*	1928	1,570	26,176,062	316,901	122				58			58
511	Rosanna, *Seminole*	1924	505	*x*	65,034					20			20
512	Sancho, *Seminole*	1929	120	359,299	11,480					6			6
513	Sasakwa, *Seminole*	1927	1,145	11,439,879	267,365					58			58

TABLE I.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
465		34	Earlsboro	Pen	S	Por			x	x		
466		31	Wilcox	Ord	S		4,839	4,844	5			
467		36	Simpson	Ord			4,853	4,886	33			
468		33	Wilcox	Ord	S		4,835		18			
469		37	Sandy Limestone				5,185 5,228	5,191 5,230	6 8		Wilcox	5,234
470		42	Hunton	Sil-Dev	L		5,110	5,156	46		Wilcox	5,511
471		38	Various	Pen, Sil-Dev, Ord	S, L	Por	x	x	x	x		
472		37	Wilcox	Ord			4,111	4,119	8			
473		38	Hunton	Sil-Dev	L		3,863	3,879	16			
474		37	Simpson	Ord	D		5,125	5,238	113			
475		35	Viola, Wilcox	Ord			4,582 4,835	4,620 4,838	38 3			
476		38	1st Wilcox	Ord			5,234	5,244	10			
477		39	Viola	Ord	L		4,140	4,140			2 Wilcox	4,695
478		36	Dolomite				5,118	5,130	12		Wilcox	5,304
479		36	Earlsboro	Pen	S							
480		36	Various	Mis, Sil-Dev, Ord	S, L		2,500	4,250				
481		36	Booch, Gilcrease, Cromwell	Pen	S					ML		
482		40	Cromwell	Pen	S	Por			20	A	Cromwell	
483			Cromwell	Pen								
484		39	Cromwell	Pen			3,450	3,451				
485		40	Various	Pen, Sil-Dev, Ord	S, L	Por			30	A		
486		40	Misener, Hunton, Wilcox	Mis, Sil-Dev Ord	S, L	Por	4,180	4,205		A	Wilcox	4,210
487		37	Various	Pen, Ord	S	Por		3,400		AF	Wilcox	4,226
488		37	Wapanucka-Cromwell, Wilcox	Pen, Ord	S		4,176	4,189	13			
489		40	Hunton	Sil-Dev			4,128	4,150	22			
490		35	Boggy, Calvin	Pen	S		2,947	2,959				
491		38	Earlsboro, Hunton, Wilcox, Simpson Dolomite	Pen, Sil-Dev, Ord	S, L		x	x	x			
492		39	Calvin, Hunton, Wilcox	Pen, Sil-Dev, Ord	S, L		x	4,250	x			
493		41	Hunton, Wilcox	Sil-Dev, Ord	S, L					A	Wilcox	4,680
494		39	Calvin, Hunton, Wilcox	Pen, Sil-Dev, Ord	S, L	Por	4,200	4,225	25	A	Wilcox	4,225
495		36	Booch	Pen			3,168	3,192	24			
496		40	Simpson	Ord		x	4,030	4,050	20	x	x	x
497		33	Hunton	Sil-Dev	L		4,160		10			
498		36	Thurman, Boggy	Pen	S		2,991	3,003	12	x		
499		38	Booch	Pen	S		x	x	x			
500		40	Misener, Hunton, Wilcox	Mis, Sil-Dev, Ord	S, L	x			x	x	Wilcox	4,483
501		36	Earlsboro, Cromwell, Simpson	Pen, Ord	S		x	x				
502		39	Earlsboro	Pen	S		x	x	x			
503		37	Hunton, Viola, Wilcox	Sil-Dev, Ord	S, L		2,697	2,714	17			
504		36	Boggy, Calvin	Pen	S	Por	x	4,100	x	x		
505		38	Various	Pen, Ord	S	x	x	x	x	x		
506		36	Various	Pen, Ord	S		4,282	4,289	7			
507		41	Hunton, Dolomite, Wilcox	Sil-Dev, Ord								
508		38	Senora	Pen			4,378	4,380	2			
509		39	Wilcox	Ord	S		x	4,300	x			
510		39	Hunton, Wilcox	Sil-Dev, Ord	S, L		3,034	3,054	20			
511		38	Booch	Pen	S							
512		37	Gilcrease, Cromwell	Pen	S		2,793	4,187				
513		36	Various	Pen, Ord	S, L							

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1943 Number of Wells	
			Oil	To End of 1943	During 1943	Completed to End of 1943	During 1943 Completed	During 1943 Abandoned	End of 1943 Temporarily Shut Down	End of 1943 Producing Oil[c]	End of 1943 Producing Gas[c]	Flowing	Artificial Lift
514	Sasakwa, East, *Seminole*	1937	40	58,361	5,417					2			2
515	Sasakwa Townsite, *Seminole*	1933	175	2,501,279	72,574					8			8
516	Searight, *Seminole*	1926	2,110	34,895,368	300,054	145	1			56			56
517	East, *Seminole*	1939	80	187,208	7,608					4			4
518	North, *Seminole*	1934	451	3,856,130	167,763	19				13			13
519	Seminole City, *Seminole*	1926	4,635	132,648,187	1,817,859	411				195			195
520	Seminole: East, *Seminole*	1926	1,680	9,053,171	242,403	134				84			84
521	North, *Seminole*	1940	100	106,252	23,833					7			7
522	West, *Seminole*	1935	500	14,264,926	473,914	43				35			35
523	Swan, *Seminole*	1938	10	17,137	1,434					1			1
524	Sylvian, *Seminole*	1941–42	300	141,110	103,228		2			7			7
525	Northeast, *Seminole*	1942	40	30,517	15,302					2			2
526	Transco, *Seminole*	1926	40	104,143		Abandoned							
527	Traugh: Deep, *Seminole*	1937	140	985,394	50,709					10			10
528	Shallow, *Seminole*	1937	270	986,914	69,861					24			24
529	Tyrola, *Seminole*	1937	100	96,878	9,785					3			3
530	East, *Seminole*	1943	80	5,258	5,258	1	1			1			1
531	Wetley, *Seminole*	1927	675	572,934	28,834					15			15
532	Wewoka, *Seminole*	1923	2,015	34,655,802	303,136					80			80
533	East, *Seminole*	1927	365	1,577,529	34,727					8			8
534	North, *Seminole*	1940	100	282,073	56,080					5			5
535	Northeast, *Seminole*	1941	200	909,869	264,994					20			20
536	Wewoka Lake, *Seminole*	1943	160	6,841	6,841	1	1			1			1
537	Wewoka Townsite, *Seminole*	1924	345	6,225,799	113,487					25			25
538	Wofford, *Seminole*	1935	60	679,661	11,519					3			3
539	Miscellaneous, *Seminole*		160	125,587	23,912					13			13
540	Aggregate for district of pools marked *x*			4,196,837									
541	Total Seminole Area		104,336	1,207,814,731	27,222,975					4,732			
	SOUTHEASTERN OKLAHOMA												
542	Ardmore, *Carter*	1942	80	86,084	73,427					2			2
543	Brock, *Carter*	1922	765	3,708,594	85,837					127			127
544	Caddo, *Carter*	1939	40	50,763	8,233					1			1
545	Caddo (Deep), *Carter*	1942	80	149,058	93,644					1		1	
546	Centrahoma, *Coal*	1937	80	126,751	18,846					3			3
547	Clarita, *Coal*	1937	40	84,511	7,572					3			3
548	Miscellaneous, *Coal*	1940	10	1,413	None					1			1
549	Pauls Valley, *Garvin*	1942	1,700	2,792,814	1,989,446	58	43			58			1
550	Miscellaneous, *Garvin*	1936		15,364	None					1			1
551	Citra, *Hughes*	1937	20	6,130		Abandoned							
552	Overbrook, *Love*	1943	10	1,320	1,320	1	1			1			1
553	Miscellaneous, *Love*	1937	40	4,617	420					1			1
554	Byars, *McClain*	1939	280	603,090	140,078		7			12			12
555	Aylesworth, *Marshall*	1942	40	54,774	49,529					3			3
556	Cumberland, *Marshall*	1940	2,170	9,290,173	3,757,621	86	27			87			1
557	Enos, *Marshall*	1933	265	174,515	11,315					23			23
558	Isom Springs, *Marshall*	1931	380	230,997	31,755		15			75			75
559	Kingston, *Marshall*	1932	115	18,232	730					9			9
560	Madill, *Marshall*	1925	275	1,134,260	8,760					73			73
561	Miscellaneous, *Marshall*	1932	20	*x*	None					1			1
562	Ada, East, *Pontotoc*	1928	325	302,090	20,805					13			13
563	Allen (shallow), *Pontotoc*	1913	2,530	8,935,208	100,740					183			183
564	Bebee, *Pontotoc*	1923	2,530	14,028,006	922,720					214			214
565	East, *Pontotoc*	1930	215	473,599	44,177					23			23

TABLE I.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft. Top Prod. Zone	Depth, Avg. Ft. Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole, Ft.
514		31	Senora		S		1,265	1,275	10		Gilcrease	2,610
515		37	Wilcox	Ord	S	Por	4,047	4,050	3	x		
516		38	Hunton, Wilcox	Sil-Dev, Ord	S, L	Por	4,120	4,325	x	x		
517		39	Cromwell	Pen	S		3,775	3,791	16	x		
518		32	Wilcox	Ord	S	x	4,596	x	x	x		
519		39	Various	Pen, Mis, Sil-Dev, Ord	S, L	Por				x	x	
520		38	Cromwell, Hunton, Wilcox	Pen, Sil-Dev	S, L			3,514				
521		31	Senora	Pen								
522		42	Calvin, Wilcox	Pen, Ord	S	Por	4,085	4,115	30	A	Wilcox	4,150
523		36	Thurman		S		2,671	2,691	20			
524		34	1st Wilcox, Cromwell	Ord, Pen			4,366	4,384	18			
525		37	Cromwell	Pen	S		3,652		10			
526		36	Calvin, Senora	Pen			2,159	2,174	15			
527		36	Simpson, Wilcox	Ord	S			x	x			
528		33	Earlsboro	Pen	S		2,347	2,360	13			
529		37	Hunton	Sil-Dev	L		3,317	x	x			
530		26	Senora		S		1,745	1,760	15			1,809
531		35	Hunton	Sil-Dev	L		2,420	2,585	165			
532		37	Cromwell, Hunton, Wilcox	Pen, Sil-Dev, Ord	S, L	Por						
533		38	Hunton, Wilcox	Sil-Dev, Ord	S, L		4,214	x	x			
534		41	Wilcox	Ord								
535		36	Misener, Hunton	Mis, Sil-Dev			3,940	3,995				
536		40	Booch				3,334	3,344	10			
537		38	Various	Pen, Sil-Dev, Ord	S, L							
538		40	Boggy, Wilcox	Pen, Ord	S		x	x	x			
539		38	Senora, Calvin, Hunton	Pen, Sil-Dev	S, L							
540												
541												
			SOUTHEASTERN OKLAHOMA									
542		39	Springer	Pen	S		3,302		40			
543		32	Ordovician, Arbuckle	Ord, Cam	S	Por		2,100		AF	Ord Lime	3,000
544		35	Woodford	Mis	S		4,170	4,324	154			
545		41	Bromide	Ord	S		5,412		15			
546		38	McAlester sand, Viola	Pen, Ord	S, L		5,970	6,235	265			
547		39	Atoka		S		790	836	46			
548			Cromwell	Pen			1,835	1,900				
549		42	Bromide	Ord	S		3,950		50			
550												
551		34	Bromide, McLish	Ord	S		5,755	5,994	x			
552		39	Springer		S		3,160	3,200	40			
553		34										
554		37	Layton, Viola	Pen, Ord	L		3,485	3,623	138			
555			Tulip Creek	Ord	S		3,110		10			
556		37	Bromide, McLish	Ord								
557		26	Preston, Arbuckle	Ord, Cam								
558		26	Stray sand		S		537	540	3			
559		26	Cretaceous, Trinity									
560		40	Bilbo, Arbuckle	Ord, Cam	S		402					
561												
562		27	Boggy, Senora	Pen	S		1,790	1,795	5			
563		30	Allen									
564		36	Boggy, Hunton, Viola	Pen, Sil-Dev, Ord								
565		35	Senora, Hunton, Viola, Simpson	Pen, Sil-Dev, Ord	S, L							

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1943	
							During 1943		End of 1943			Number of Wells	
			Oil	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
566	Conservation, *Pontotoc*	1927	285	551,173	20,805					13			13
567	Fitts, *Pontotoc*	1933	5,955	98,485,594	2,371,935	989				639			639
568	North, *Pontotoc*	1934	150	586,172	23,376					15			15
569	South, *Pontotoc*	1937	205	543,414	53,982					22			22
570	West, *Pontotoc*	1937	175	516,960	48,173					11			11
571	Francis, *Pontotoc*	1918	60	*x*	None					1			1
572	West, *Pontotoc*	1917	60	*x*	5,110					7			7
573	Jesse, *Pontotoc*	1935	1,235	6,235,286	617,931					56			56
574	Oakman, *Pontotoc*	1935	80	29,750	1,098					5			5
575	Roper, *Pontotoc*	1942	190	110,776	89,956					6			6
576	Steedman, *Pontotoc*	1920	50	23,310	None					1			1
577	North, *Pontotoc*	1928	305	1,807,487	74,460					13			13
578	Miscellaneous, *Pontotoc*		50	7,344	None								
579	Aggregate for district of pools marked *x*			241,382									
580	Total Southeastern Oklahoma		20,810	151,411,011	10,673,801					1,704			
	SOUTHWESTERN OKLAHOMA												
581	Sayre, *Beckham*	1923		304,519		Abandoned							
582	Apache, *Caddo*	1941	1,000	4,226,993	2,303,185	29	2			28			1
583	Binger, *Caddo*	1934	80	86,749	None					1			1
584	Cement, *Caddo*	1917	4,505	28,733,982	2,575,451	501	14			369			1
585	Miscellaneous, *Caddo*			6,565	None	Abandoned							
586	Ed Cox, *Carter*	1925	770	885,409	76,650					42			42
587	Fox, *Carter*	1917–35	1,100	15,152,679	258,785					94			94
588	Graham, *Carter*	1917	2,990	27,068,772	317,915					255			255
589	Healdton, *Carter*	1913	7,550	195,988,994	2,613,583	2,365	4			1,876			1,876
590	Hewitt, *Carter*	1919	4,530	98,205,806	2,368,096	1,103	2			906			906
591	Sholem Alechem, *Carter*	1923	4,760	39,511,873	793,174	401				304			304
592	Tatums, *Carter*	1927	2,660	17,349,214	605,236	247				209			209
593	Tussy, *Carter*	1933	1,340	6,307,503	868,304		7			111			111
594	Wheeler, *Carter*	1916	755	*x*	10,220					37			37
595	Wildcat Jim, *Carter*	1914	1,235	*x*	512,095		2			87			87
596	Miscellaneous, *Carter*		40	2,257	459					4			4
597	Fort Sill Reservation, *Comanche*	1943	160	46,024	46,024	16	16			10			10
598	Hanbury, *Comanche*	1920	280	*x*	2,190					5			5
599	Lawton, *Comanche*	1915	960	*x*	2,555		1			94			94
600	Walters, *Cotton*	1917	3,790	25,976,274	258,785					218			218
601	Robberson, *Garvin*	1921	2,410	15,777,199	287,672	328				166			166
602	Knox, *Grady*	1924	1,990	16,041,876	490,855	272	3			178			178
603	Miscellaneous, *Grady*	1923	40	*x*	4,015					1			1
604	Altus, *Jackson*	1934	1,740	1,946,796	172,322		4			114			114
605	Tipton, *Jackson*	1935	880	1,972,866	132,230		1			57			57
606	Oscar, *Jefferson*	1924	685	11,016,538	383,980					191			191
607	Seay, *Jefferson*	1924	325	559,475	15,330		2			42			42
608	Spring, *Jefferson*	1924	265	*x*	148,555					38			38
609	Hobart, *Kiowa*	1939	500	1,420,731	70,668					23			23
610	Stockton, *Love*	1937	40	64,462	7,337					1			1
611	Comanche, *Stephens*	1918	925	10,694,746	139,795					143			143
612	Cruce, *Stephens*	1926	100	*x*	5,840					3			3
613	Doyle, *Stephens*	1921–37	315	*x*	247,105		6			38			38
614	West, *Stephens*	1939	100	155,252	28,711					3			3
615	Duncan: North, *Stephens*	1920	1,260	4,483,108	127,020					79			79
616	West, *Stephens*	1919	910	6,103,932	103,660					74			74
617	Empire, *Stephens*	1920	2,630	*x*	632,545		5			266			266
618	Loco, *Stephens*	1915	575	1,623,771	50,370		33			64			64
619	West, *Stephens*	1941	360	189,182	168,881					35			35

TABLE I.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
566		30	Boggy, Hunton	Pen, Sil-Dev							Wilcox	3,062
567		39	Various	Pen, Sil-Dev, Ord	S, L							
568		32	McAlester, Gilcrease	Pen	S		1,767	*x*	*x*			
569		35	Gilcrease, Hunton, Viola	Pen, Sil-Dev, Ord	S, L							
570		39	Cromwell	Pen	S		3,021	3,110	89			
571		26	Allen, Senora	Pen			1,200	2,000				
572		27	Allen, Senora	Pen								
573		40	Hunton, McLish	Sil-Dev, Ord	L, S							
574		29	Boggy	Pen	S		1,160	1,169	9			
575		38	Viola	Ord	L		2,531		41			
576		31	Boggy	Pen								
543		31	Boggy	Pen								
578			Hunton	Sil-Dev	L							
579												
580												
SOUTHWESTERN OKLAHOMA												
581		34	Deese	Pen	S	Por		*x*	*x*			
582		39	Simpson	Ord			3,395	3,430				
583		38	Deese	Pen								
584		34	Various	Per, Pen	S		1,900	1,600				
585			Miscel, Caddo									
586		22	Pontotoc, Deese	Pen			1,250	2,910	30			
587		31	Fox sand, Simpson, Oil Creek	Pen, Ord	S		2,200	2,500		A		
588		31	Deese	Pen	S	28-30				A	Dornicks Hills	5,180
589		31	Various	Pen, Ord	S, L		920	3,500		AF	Arbuckle	*x*
590		34	Hewitt, Viola	Pen, Ord	S	15-20	920	2,700		AF	Arbuckle	*x*
591		29	Hoxbar, Deese	Pen	S	30	1,890	4,000		A		
592		27	Deese, Arbuckle	Pen, Ord	S	30			60			
593		23	Deese	Pen	S	Por			*x*	A		
594		20	Pontotoc	Pen	S	*x*				A		
595		24	Pontotoc, Deese	Pen			1,552	2,890				
596		20										
597		36	Permian	Per	S		790	943	153			
598		38	Various	Pen	Gw, S		1,640	2,100				
599		30										
600		34	Cisco, Hoxbar				2,100	2,400				
601		23	Pontotoc, Simpson	Pen, Ord	S, L	*x*	1,200	1,900		A		
602		35	Pontotoc	Pen	S	15–20	1,700	2,200	15	AF		8,963
603			Pontotoc	Pen								
604		41	Granite wash	Pen	Gw	Por			30	D		
605		40	Canyon, Arbuckle	Ord	L		*x*	*x*	*x*			
606		33	Glenn	Pen	S		1,180	1,610	25			
607		35	Cisco, Hoxbar				1,100					
608		35	Hoxbar				2,095	2,101	6			
609		35	Pontotoc, Conglomerate	Pen	L		1,091	1,107	16			
610		36	Unidentified		S		6,893	6,927	34			
611		34	Stray, Wilson, Pace		S		1,400	1,800				
612		30	Upper Penn	Pen	S		800	1,900				
613		30	Permian, Hoxbar, Deese				1,100	1,250				
614		42	Deese	Pen	S		5,578	5,614	36			
615		36	Thomas				1,700	2,300				
616		33	Brown, Blaydes				1,700	2,300				
617		39	Various				1,600	2,300				
618		23	Pontotoc, Deese	Pen	S		850	1,550				
619		34	Sandy Lime				1,113	1,135				

which is a well-known geological feature, and brought into play the most intensive and concentrated geophysical activity that the state has ever witnessed.

Other of the more important discoveries are the Big Bend pool, Osage County; West Burnett, Pottawatomie County; North McLoud, Lincoln County; and, the Horns Corner pool, Hughes County. The Big Bend pool, at the close of the year, had four producing oil wells with an accumulated production of 104,705 bbl. of 41° gravity oil. Production is from the Layton sand at 2850 ft. West Burnett, a December discovery in sec. 19, 8 N., 2 E., was completed for an initial production of 350 bbl. in the second Wilcox sand at 6250 ft.; North McLoud, an April discovery in sec. 10, 12 N., 2 E., had three producing wells at the end of the year, with an accumulated production of 35,600 bbl. of 37° gravity oil from the Wilcox sand at 5640 ft.; and Horns Corner had five producing wells with a total production of 156,000 bbl. of 37° gravity crude from the Cromwell sand at 3880 feet.

New producing horizons developed in pre-1943 discovered pools were as follows: Burgess sand in the Slick pool, Creek County; Medrano and Pennsylvanian sand in the Cement pool, Caddo County; Oil Creek in the Cumberland pool, Marshall County; Canyon Creek sand in the Frederick pool, Tillman County; Prue sand in the Hickory Grove pool, Creek County; Earlsboro sand in the Romulus pool, Pottawatomie County; the Skinner sand in the East Sporn pool, Lincoln County; Hunton lime in the Sylvian pool, Seminole County; Bartlesville sand in the East Watchorn pool, Pawnee County; and the Gilcrease sand in the Wewoka pool in Seminole County.

During 1943, water-flood operations were limited to expansion of existing floods concentrated in Rogers, Wagoner and Nowata Counties, in the northeastern shallow areas.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1943	
							During 1943		End of 1943			Number of Wells	
			Oil	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
620	Milroy: Deep, *Stephens*	1937–39	80	641,922	105,460					1			1
621	Shallow, *Stephens*	1916	800	3,558,726	100,375					142			142
622	Palacine, *Stephens*	1929	120	194,935	13,140					3			3
623	Rainola, *Stephens*	1921	150	*x*	26,280					18			18
624	Velma, *Stephens*	1917–41	4,110	7,161,586	604,075		23			664			664
625	North, *Stephens*	1942	40	13,722	9,077					1			1
626	Woolsey, *Stephens*	1922	170	*x*	20,440		3			17			17
627	South, *Stephens*	1942	60	86,056	45,517					8			8
628	Miscellaneous, *Stephens*		140	77,414	23,157					11			11
629	Frederick, *Tillman*	1937	100	37,097	5,563		1			3			3
630	West, *Tillman*	1937–39	300	3,094,544	354,354					29			29
631	Red River Bed, *Tillman*	1920	500	*x*	99,280		1			80			80
632	Sentinal, West, *Washita*	1943	200	1,222	1,222	1	1			1			1
633	Aggregate for district of pools marked *x*			41,966,956									
634	Total Southwestern Oklahoma		61,325	588,737,727	18,237,538					7,144			
635	Total Oklahoma		797,814	5,188,465,983	121,430,513					52,095			

DEMAND FOR CRUDE

Demand for crude was strong throughout the year. Because of a decline in production, many local refiners were constantly on the alert for sufficient crude to maintain economic operation.

IMPORTANT DEVELOPMENT IN POOLS DISCOVERED PRIOR TO 1943

Crescent.—Completions in the Crescent pool total 7. Of these, six are oil wells with an average initial of 220 bbl. and one a dry hole. At the end of the year 50 wells producing from the Wilcox and Layton formations averaged 2100 bbl. daily. The daily average for the entire year was 2086 bbl. and the accumulated production to Jan. 1, 1944 amounted to 14,965,000 barrels.

Oklahoma City.—In the Oklahoma City pool, a 1928 discovery and the state's most prolific field, six oil wells with an average initial production of 187 bbl. and one dry hole were drilled. During 1943 the pool produced 20,224,000 bbl., or 16.7 per cent of the state's total. The pool's cumulative recovery to Jan. 1, 1944 of 602,676,000 bbl. represents 11.6 per cent of the entire state's cumulative production. At the close of the year production was averaging 48,500 bbl. from 839 wells. While production in this pool has come from several zones, 80 per cent of the current production and 74.3 per cent of the pool's total recovery is from the Wilcox sand. Production averaged 55,409 bbl. daily during the year, a decline of 16,673 bbl. (23.1 per cent) from the preceding years average.

East Watchorn.—Six oil wells were added to the East Watchorn pool with an average initial of 324 bbl., and one gas well with an initial of 6,500,000 cu. ft. At the close of the year 22 wells were averaging 2400 bbl. daily and the accumulated production to Jan. 1, 1944, amounted to 1,456,500 bbl. This pool is believed to be fully developed. Production is from the Wilcox and Bartlesville sands at 3930 and 3550 ft., respectively.

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1943	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age	Character	Porosity	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
620		42	Hunton, Oil Creek	Sil-Dev			7,554	7,625	71			
621		26	Pontotoc	Pen								
622		36	Pennsylvanian, Arbuckle	Pen, Ord								
623		36	Smith, Brown	Pen								
624		26	Permian, Glenn, Bromide	Per, Pen, Ord	S							
625		43	Bromide	Ord	S		7,000		100			
626		32	Permian, Glenn	Per, Pen								
627			Arbuckle	Cam-Ord	L		1,783		22			
628		36	Deese	Pen	S							
629		39	Canyon, Strawn	Ord	L, S		3,081					
630		37					4,215	4,218	3			
631		39	Cisco				1,540	1,700	19			
632		34	Granite Wash	Pen	Gw		5,444	6,591	33			9,971
633												
634												
635												

TABLE 2.—*Important Wildcats Drilled in* 1943

County	Location			Total Depth, Ft.	Surface Formation	Deepest Formation Tested	Drilled by	Initial Production per Day, Oil, U. S. Bbl.	Choke or Bean, Fraction of Inch	Pressure, Lb. per Sq. In.		Remarks
	Sec.	Twp.	Rge.							Casing	Tubing	
Comanche	25	4N	11W	4,261	Permian	Arbuckle	Texas Co.					Dry and abandoned
Atoka	18	3S	10E	3,754	Cretaceous	Simpson	Burns Oil Co.					Dry and abandoned
Pottawatomie	21	8N	3E	4,995	Permian	Viola	Mid-Cont. Petr. Corp.					Dry and abandoned
Pottawatomie	32	8N	3E	5,451	Permian	Simpson	Kerlyn Oil Co.	306	9/24		75	Hunton ls. 4664 to 4760 ft.
Payne	8	18N	1W	5,684	Pennsylvanian and Permian	Simpson	Lewis Prod. Co.					Dry and abandoned
Garfield	27	21N	6W	7,530	Permian	Simpson	Champlin O. & R. Co.					Dry and abandoned
Noble	15	21N	2E	4,489	Pennsylvanian and Permian	Simpson	L. H. Wentz					Dry and abandoned
Garvin	20	3N	1E	3,963	Permian	Viola	H. Culver et al.					Dry and abandoned
Pottawatomie	28	10N	2E	5,885	Pennsylvanian and Permian	Simpson	Stanolind-Amerada	347	1/18	1,310	790	1st Wilcox sd. 5877 to 5885 ft.
Lincoln	7	13N	3E	5,336	Pennsylvanian and Permian	Simpson	Magnolia					Dry and abandoned
Payne	28	20N	4E	4,156	Pennsylvanian and Permian	Simpson	Amerada-Stanolind	191		150		Misener sand, 4029 to 4048 ft.
Comanche	8	3N	10W	1,122	Permian	Simpson	Texas Co.					Permian production (gas)
Hughes	19	7N	10E	4,961	Alluvium	Simpson	Burke-Greis					Dry and abandoned
Noble	14	22N	1E	4,669	Pennsylvanian and Permian	Simpson	Superior	10				Tonkawa 2562 to 2750 ft. (OWDD)
Noble	12	21N	2W	5,251	Pennsylvanian and Permian	Simpson	Atlantic	300				Misener 5050 to 5064 ft.
Garvin	11	3N	1W	4,956	Alluvium and Permian	Simpson	H. L. Hurst					Dry and abandoned (OWDD)
Lincoln	10	12N	2E	5,641	Pennsylvanian and Permian	Simpson	Stanolind	205	7/8	275		Wilcox 5635 to 5641 ft.
Creek	10	14N	7E	3,375	Permian	Deese	Sun Oil Co.	63				Prue sand 2730 to 2752 ft.
Osage	20	25N	3E	2,850	Permian	Mis. lime	A. G. Oliphant	300	5/8			Lower Layton 2850 to 2875 ft.
Tillman	33	2S	17W	4,818	Permian	Arbuckle	Kerlyn Oil	20				Pay 2673 to 2695 ft.
Oklahoma	32	14N	4W	7,690	Permian	Simpson	A. Gutowsky	535	1/4			Hunton 6938 to 6956 ft.
Caddo	30	6N	10W	8,320	Permian	Simpson	Amerada					Dry and abandoned
Pottawatomie	19	9N	2E	6,232	Permian	Simpson	Hall & Briscoe					Dry and abandoned
Seminole	3	10N	7E	4,510	Pennsylvanian	Simpson	Kerlyn Oil	14	1/8			Hunton 4183 to 4188 ft.
Pittsburg	24	8N	16E	6,292	Pennsylvanian	Caney	Phillips					Dry and abandoned
Beckham	35	10N	23W	6,513	Permian	Penn.	Northern Ord., Inc.					Dry and abandoned
Carter	18	5S	1W	4,949	Arbuckle	Trenton	Stanolind					Dry and abandoned
Okfuskee	7	13N	7E	4,214	Pennsylvanian	Simpson	Northern Ord., Inc.					Hunton (gas) 4009 to 4026 ft.
Garvin	2	1N	3W	10,996	Permian	Viola	Amerada					Dry and abandoned
Coal	22	3N	9E	6,174	Pennsylvanian	Arbuckle	Stanolind					Cromwell prod. (gas) 3524 to 3564 and 3578 to 3590 ft.
Hughes	29	7N	10E	3,883	Pennsylvanian	Cromwell	Deep Rock	572				Cromwell prod. 3872 to 3883 ft.
Beckham	25	9N	22W	6,010	Permian	Penn.	Northern Ord., Inc.					Dry and abandoned
Cleveland	11	10N	1W	6,603	Permian and Pennsylvanian	Simpson	Deep Rock	945	3/8			Simpson dolomite 6498 to 6521 ft.
Caddo	33	5N	11W	4,755	Pennsylvanian	Atoka	Texas Co.					Dry and abandoned
Okfuskee	24	12N	8E	3,504	Pennsylvanian	Cromwell	Midco Oil Co.	2,445	1/4	850	220	Cromwell 3488 to 3504 ft.
Garvin	24	3N	1W	4,650	Permian	Simpson	Pure					Dry and abandoned
Washita	31	8N	17W	4,714	Pennsylvanian	Viola	Gulf					Dry and abandoned
Garvin	17	3N	2E	4,330	Pennsylvanian	Arbuckle	Ohio					Basal Permian (gas) 2887 to 2920 ft.
Cimarron	16	5N	8E	6,280	Pennsylvanian	Arbuckle	Pure					Penn. ls. (gas) 4670 to 4750 ft.
Logan	16	15N	2W	6,246	Permian	Simpson	Eason					Bartlesville (gas) 5687 to 5697 ft.
Bryan	22	6S	7E	6,282	Alluvium and Cretaceous	Simpson	Amerada					Dry and abandoned
Noble	1	20N	1W	3,524	Pennsylvanian and Permian	Perry gas sd.	T. E. Berry	150				Perry sd. 3494 to 3496 ft.
Kiowa	1	7N	17W	7,880	Permian	Viola	Kerlyn					Dry and abandoned

TABLE 2.—(*Continued*)

County	Location			Total Depth, Ft.	Surface Formation	Deepest Formation Tested	Drilled by	Initial Production per Day, Oil, U. S. Bbl.	Choke or Bean, Fraction of Inch	Pressure, Lb. per Sq. In.		Remarks
	Sec.	Twp.	Rge.							Casing	Tubing	
Logan	18	18N	3W	6,423	Pennsylvanian and Permian	Simpson	Danciger O. & G. et al.					Dry and abandoned
Love	6	6S	2E	4,510	Pennsylvanian	Caney	Mudge Oil Co.	6.5				Springer 3160 to 3202 ft.
Marshall	30	8S	6E	2,056	Cretaceous	Simpson	Texas Co.					Dry and abandoned
Love	34	6S	2E	6,000	Cretaceous	Simpson	Mid-Cont. Petr. Corp.					Dry and abandoned
Stephens	30	1N	5W	1,718	Pennsylvanian	Pennsylvanian	T. H. McCasland	[1]				Penn. (gas) 1691 to 1714 ft.
Noble	29	22N	1W	5,139	Pennsylvanian and Permian	Simpson	Sinclair Prairie					Dry and abandoned
Coal	3	2N	9E	6,355	Pennsylvanian	Caney	Continental					Dry and abandoned
Noble	25	22N	1E	4,429	Pennsylvanian and Permian	Simpson	Barnsdall	14				Burgess 4394 to 4414 ft.
Woodward	28	22N	17W	10,073	Quaternary	Simpson	Northern Ord., Inc.					Dry and abandoned
Noble	24	23N	2W	4,892	Pennsylvanian and Permian	Simpson	Northern Ord., Inc.					Dry and abandoned
Oklahoma	7	11N	4W	8,650	Permian	Simpson	L. S. Youngblood					Dry and abandoned
Payne	25	19N	4E	3,776	Pennsylvanian and Permian	Viola	J. E. Crosbie	331	¼	850	550	Misener 3750 to 3756 ft.
Hughes	36	8N	11E	4,836	Pennsylvanian	Simpson	Northern Ord., Inc.					Dry and abandoned
Cleveland	29	10N	3W	8,800	Permian	Simpson	Mid-Cont. Petr. Corp.	248 3 hr	8/64–59/64			Second Wilcox 8787 to 8800 ft.
Pottawatomie	19	8N	2E	6,251	Permian	Simpson	Stanolind	350	2/18			Second Wilcox 6241 to 6251 ft.
Oklahoma	9	13N	1E	5,885	Pennsylvanian and Permian	Simpson	Stanolind	41				Hunton 5543 to 5556 ft.
Logan	22	17N	3W	6,330	Quaternary	Simpson	Gulf	49				Layton 4756 to 4770 ft.
Noble	1	21N	1E	4,597½	Pennsylvanian and Permian	Simpson	Gulf	926 est.				Second Wilcox 4590 to 4597.5 ft.
Washita	8	8N	20W	9,971	Permian	Arbuckle	Gulf	345				Granite wash 5554 to 5620 and 6425 to 6591 ft.

	In Proven Fields	Wildcats
Number of Wells Drilling, December 1943	295	85
Number of Oil Wells Completed, 1943	541	46
Number of Gas Wells Completed, 1943	100	27
Number of Dry Holes Completed, 1943	313	260

[1] 11,000 M cu. ft. gas.

Cement.—An outstanding discovery of production in new horizons in old pools is that of the Medrano sand development in the Cement pool, Caddo County. Discovered in February, 13 oil wells had been completed at the end of the year, with an accumulated production of approximately 423,000 bbl. The Medrano sand is encountered at approximately 5700 ft. and the 13 wells were producing 2500 bbl. daily, an average of 192 bbl. per well at the close of the year.

Cumberland.—In the Cumberland pool, a new source of production was established in the Oil Creek sand. This lower Simpson pay no doubt will add materially to the reserves of the pool. Twenty-seven oil wells with an average initial production of 1487 bbl. and three dry holes were added to the Cumberland pool during 1943. At the end of the year the pool had 87 wells producing a total of 12,200 bbl. daily under restricted production. Total 1943 production amounted to 3,758,000 bbl. and the total cumulated production to Jan. 1, 1944, amounted to 9,290,000 barrels.

To prevent the Cumberland pool from being inundated by impounded waters upon completion of the Denison Dam project, the Federal Government has spent several million dollars on a system of dikes and channels. Excavation of two large channels to protect the Cumberland field from the Washita River arm of the Denison Dam reservoir has been finished. Construction work still is in progress on three dikes, which will block off the Washita River and will crest at the 646-ft. elevation.

Pauls Valley.—Largely owing to modification of the 40-acre Federal Well Spacing Order M-68 to permit 20-acre spacing, the Pauls Valley pool, Garvin County, shared in the state's 1943 development to the extent of 43 oil wells, with an average initial of 1784 bbl., and two dry holes. At the close of the year there were 58 wells at Pauls Valley, producing 10,000 bbl. daily under production restrictions of state authorities. Total production for the year amounted to 1,989,000 bbl. and total production from April 1942, the date of discovery, to Jan. 1, 1944, amounted to 2,793,000 barrels.

Velma.—In the Velma pool, Stephens County, discovered in 1917, 21 wells were completed with an average initial of 113 bbl.; two gas wells, with a combined initial of 2,380,000 cu. ft., and 15 dry holes. Four wells were reconditioned, of which three were oil wells with a total initial of 46 bbl. and one was a gas well with an initial of 2,000,000 cu. ft. This development was influenced by discovery of production in the Simpson zone. The Velma pool produced 604,000 bbl. of oil during 1943, with an accumulated total to the end of the year of 7,162,000 bbl. The pool's 664 wells were producing 1750 bbl. at the close of the year.

NATURAL GAS

Gas production activities were in the main confined to three areas: Hugoton, in the northwest sector; Chickasha, in the south central; and the Citra-Centrahoma area, in the southeast. At the end of the year, there were 87 wells in the Oklahoma portion of the Tri-State Hugoton pool, 26 of which were drilled during the year with an average initial of 20,800,000 cu. ft. Development in Chickasha and southeast Oklahoma was not outstanding and only a few wells were drilled.

REFINERY OPERATIONS

Outstanding refinery developments during the year included the construction of a high-octane plant by the Continental Oil Co. at Ponca City, having a daily capacity of 5000 bbl., and a large unit at Duncan, which is to be operated jointly by several state refiners. Based on yearly estimates, the state's refinery throughput suffered a decrease of 6.4 per cent from the preceding year, having run to stills 162,000 bbl. daily, compared with 173,000 in 1942. The decrease reflects declining production in the state and the consignment of Oklahoma crude to out-of-state refineries as a result of the war effort.

Oil and Gas Development in Northern and Central Pennsylvania during 1943

By Arthur C. Simmons,* Member A.I.M.E.

THE area producing Pennsylvania-grade crude oil declined sharply in 1943, with a daily average production in the entire area of 71,056 bbl. as against a daily average in 1942 of 77,786. The total decline in the Pennsylvania-grade area amounted to 2,456,311 bbl., and 1,981,271 bbl. of this occurred within the state of Pennsylvania.

TABLE 1.—*Production of Pennsylvania Grade in* 1943
DAILY AVERAGE PRODUCTION, BARRELS

Month	Bradford Field		Allegany	Southern Pennsylvania	Ohio	West Virginia	Total
	Pennsylvania	New York					
January	35,112	3,392	9,954	8,832	4,001	9,548	70,839
February	35,333	3,406	10,288	8,760	4,286	9,321	71,394
March	36,360	3,606	10,917	9,504	4,678	9,516	74,581
April	35,817	3,492	10,627	9,232	4,566	9,500	73,233
May	34,618	3,445	10,374	9,595	4,549	8,774	71,355
June	35,837	3,584	10,894	9,818	4,801	9,933	74,867
July	34,501	3,465	10,568	9,434	4,668	9,064	71,700
August	33,958	3,369	10,431	8,985	4,990	8,968	70,701
September	33,566	3,406	10,621	9,507	4,966	9,134	71,200
October	31,135	3,206	9,746	9,106	4,739	8,968	66,900
November	31,997	3,237	10,064	9,728	4,053	8,365	67,394
December	31,116	3,088	10,146	9,129	4,022	8,205	65,706
Daily average	34,100	3,391	10,385	9,304	4,528	9,105	71,056

The principal decline occurred in the Bradford field, where it was caused primarily by a drastic reduction in well completions.

All of the zones in the Pennsylvania-grade producing area showed a decline except the part of Ohio that produces that grade, where production increased very slightly over 1942. Table 1 shows the average daily production by months for the several districts of the area. Table 2 is a comparison of the production in the two districts within the state of Pennsylvania. It is interesting to note that the Bradford field produced approximately half the total quantity of Pennsylvania grade but accounted for nearly three-fourths of the decline in production from the previous year. It is believed that this decline is occasioned by restrictive price ceilings and a lack of adequate manpower to drill the necessary wells to maintain production.

STOCKS OF PENNSYLVANIA GRADE

At the beginning of 1942, stocks of Pennsylvania-grade crude totaled 3,196,000 bbl. and at the beginning of 1943 they totaled 2,626,000 bbl. At the end of 1943 the stocks of Pennsylvania-grade crude had declined to 1,052,000 bbl. The available crude stocks have been almost completely consumed, as nearly all of the present crude stocks are "unavailable" and required for

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* Consulting Petroleum Engineer, Bradford, Pennsylvania.

the maintenance of tank farms, pipe lines and refinery operations. The lack of available stocks of crude oil is confirmed in that the largest buyer on June 1, 1943, restricted deliveries to 85 per cent of contract amounts and on Jan. 1, 1944, there was an additional restriction, which reduced deliveries to 75 per cent of the contract value.

TABLE 2.—*Oil Production in the State of Pennsylvania*

	Bradford Field				Central and Southern Pennsylvania		State of Pennsylvania	
	Wells Completed[a]	Change	Oil Production, Bbl.[b]	Change	Oil Production, Bbl.	Change	Oil Production, Bbl.	Change
Total:								
1937	4,112		15,076,909		4,108,100		19,185,109	
1938	2,148	−1,964	13,417,102	−1,659,807	4,008,923	− 99,177	17,426,025	−1,758,894
1939	2,114	− 34	12,899,104	− 517,998	4,438,035	+429,112	17,337,139	− 88,886
1940	3,004	+ 890	12,748,279	− 150,825	4,604,763	+166,728	17,353,042	+ 15,903[c]
1941	3,207	+ 203	12,729,900	− 18,379	4,104,100	−500,663	16,834,000	− 519,042
1942	3,113	− 94	14,160,000	+1,430,100	3,663,870	−440,230	17,823,870	+ 989,870
1943	2,255	− 858	12,446,634	−1,713,366	3,395,965	−267,905	15,842,599	−1,981,271
Daily average:								
1937			41,300		11,255		52,555	
1938			36,759	−4,541	10,983	− 272	47,742	−4,813
1939			35,340	−1,419	12,159	+1,176	47,499	− 243
1940			34,831	− 509	12,581	+ 422	47,412	− 87[c]
1941			34,876	+ 45	11,244	−1,337	46,120	−1,292
1942			38,795	+3,919	10,038	−1,206	48,833	+2,713
1943			34,100	−4,695	9,304	− 734	43,404	−5,429

[a] Includes oil and water-intake wells and New York state part of Bradford field.

[b] Pennsylvania production only.

[c] Variance between total production and daily average occasioned by 365-day year in 1939 and 366-day year in 1940.

CRUDE-OIL PRICES

No changes in prices of crude oil occurred during 1943 but the average price of all crudes in the Pennsylvania-grade area was $0.058 higher than in 1942. In March 1942 there was an upward adjustment in prices for Pennsylvania-grade crude and no changes have taken place since that date.

NEW DEVELOPMENTS

Efforts are being made to water-flood other areas in the Pennsylvania-grade region but these experiments have not yet indicated the desirability of extensive developments.

A great deal of interest has been shown by the entire petroleum industry in the experimental mine, or horizontal well, near Franklin, Pennsylvania. During 1943 the shaft was completed to the bottom of the oil sand and two horizontal wells were extended 2500 ft. in each direction, by drilling operations carried on at the bottom of the shaft. Both of these wells were shot but have not been completely cleaned out because of the inability to secure special equipment now on order. No conclusions can yet be reached regarding the economic feasibility of horizontal drilling, although it has been definitely proved to be a mechanical or constructional success.

The Pennsylvania Grade Crude Oil Association is properly concerned with the declining production in the Pennsylvania-grade area and is exerting considerable effort to prevent further declines. Additional sums have been made available for fundamental laboratory research and the staff of the association has been enlarged for the purpose of applying generally in the field the fundamental knowledge gained from research efforts.

Oil and Gas Developments in Southwestern Pennsylvania during 1943

By John T. Galey*

A combination of two factors in addition to the current Federal drilling and price regulations reduced by 120 from 1942 the number of new wells completed in southwestern Pennsylvania during the year. No new prospective area was found comparable to the Armbrust gas pool, Westmoreland Co., which accounted for a seventh of the last year's drilling, and it is considered doubtful whether, even if such a field had been discovered, the drilling contractors, who have been seriously affected by the manpower shortage, could have drilled many more wells than they did during the year.

New wells totaling 445 were completed for a combined footage of over 1,250,000. Dry holes numbered 131 and had a footage of nearly 400,000. Old wells drilled deeper total 55, of which 17 were found nonproductive.

Shallow Development

Oil

Oil completions yielded an initial of only slightly over one hundred barrels from 21 wells for about the same per well average as that of a year ago. However, 65 bbl. of this total came from two wells in two new strikes. The footage drilled of nearly 33,000 gives an average of nearly 100 ft. less per well than a year ago. Two old wells drilled deeper had a combined initial of only 4 bbl. The largest oil well of the year, 40 bbl., was found in the Speechley (U. Dev.) sand at a depth of 3492 ft. in German township, Fayette County. The location is several miles east of the nearest oil production but as the area that could be occupied by a pool is fairly well delimited by drilling, the extent of this production would not appear to be large. The other notable oil production was found in the Dunkard (Penna.) sand, Cumberland township, Greene County, at a depth of 1065 ft. Here the first well had an initial of 9 bbl. and the second 25 bbl. However, a third proved dry, and as this area is also delimited by drilling, the pool doubtless will be of small area.

Gas

Gas completions yielded an initial of slightly over one hundred million cubic feet per day and new wells, totaling 303, account for all but four million of this volume. Old wells drilled deeper, numbering 35, found gas. The per well average in new drilling of approximately 320 M cu. ft. is nearly 165 M cu. ft. less than a year ago and the total footage is slightly over 830,000, which is about a quarter of a million feet less than in 1942. Average rock pressure of new completions is approximately 365 lb. per sq. in. The entire volume of new production is from the Upper Devonian or higher stratigraphic horizons.

In Allegheny County, the greatest activity was in Forward and Plum townships. Wells there account for more than one half the completions. One large well was drilled in Forward township and an open flow of 3.623 million cubic feet was found in an old Gantz (U. Dev.) sand area. The top of the sand was encountered

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* Oil and Gas Operator, Pittsburgh, Pennsylvania.

at 2205 ft. and the rock pressure was 525 lb. per sq. in. The only other notable completion in this county was made in Patton township, where an initial of approximately 2 million cubic feet was found in the Hundred-foot (U. Dev.) sand at a depth of 2163 ft., with a rock pressure of 1385 lb. per sq. in., which is abnormally high.

TABLE I.—*New Wells Drilled for Gas and Oil in Southwestern Pennsylvania during* 1943

County	Gas			Oil			Dry Holes		Total Number Wells Completed	Total Footage	Drilling 12/31/43
	Number of Wells	Initial Production, M Cu. Ft.	Total Depth, Ft.	Number of Wells	Initial Production, Bbl.	Total Depth, Ft.	Number	Total Depth, Ft.			
UPPER DEVONIAN AND SHALLOWER HORIZONS											
Allegheny	17	8,082	45,604	2	6	3,514	6	17,588	25	66,706	19
Armstrong	101	13,328	295,114	0	0	0	9	25,218	110	320,332	28
Beaver	0	0	0	4	4	4,966	1	1,060	5	6,026	1
Butler	11	308	18,462	10[1]	19	15,859	10	15,787	31	50,108	8
Fayette	31	11,131	67,520	1	40	4,210	22	56,965	54	128,695	22
Greene	44	21,337	127,994	2	34	2,198	24	71,895	70	202,087	35
Indiana	25	3,576	74,461	0	0	0	12	39,827	37	114,288	12
Lawrence	0	0	0	0	0	0	2	1,514	2	1,514	0
Washington	31[2]	15,105	73,610	2	4.5	2,208	7	17,063	40	92,881	20
Westmoreland	43	24,233	128,115	0	0	0	32	108,319	75	236,434	17
Total	303	97,100	830,880	21	107.5	32,955	125	355,236	449	1,219,071	162
LOWER DEVONIAN AND DEEPER HORIZONS											
Beaver	0	0	0	0	0	0	1	4,862	1	4,862	1
Butler	0	0	0	0	0	0	1	6,680	1	6,680	0
Fayette	0	0	0	0	0	0	2	15,575	2	15,575	1
Westmoreland	0	0	0	0	0	0	2	17,074	2	17,074	1
Total	303	97,100	830,880	21	107.5	32,955	131	399,427	455	1,263,262	165

[1] Includes one pressure well.
[2] Includes two storage wells.

Armstrong County leads in number of completions, most of which were made to the Bradford sand. Drilling was scattered fairly well over the entire county, but South Bend and Wayne townships, with a total of 13 each, had the greatest number of completions. The best well found was in Bethel township, where an open flow of 1.043 million cubic feet with 625 lb. rock pressure was encountered in the Hundred-foot sand at a depth of 1776 feet.

Two areas in Fayette County had large wells. In Luzerne township the Fifty-foot (U. Dev.) sand had an initial of 4 million cubic feet with 565 lb. rock pressure at 1753 ft. Spring Hill township had three wells averaging over one million cubic feet in the Big Injun (Miss.) sand at a depth of approximately 1200 ft. While there had been some drilling in this area a number of years ago, the rock pressure on these wells of 675 lb. indicates a nearly virgin reservoir. The greatest activity took place, as in the past several years, in German, Menallen and Nicholson townships and in Monongahela township, Greene County, where the Big Injun (Miss.) sand is still attracting additional drilling. Center township, Greene county, had the largest number of completions but none was of high open flow. In Perry township a well making 0.52 million cubic feet was found in the Murphy (Penna.) sand at 715 ft. Washington township had a 3.252 million cubic foot well in the Fifty-foot (U. Dev.) sand with a rock pressure of 520 lb. at a total depth of 2710 ft., and an old well deepened in Jackson township had an open flow of 1.861 million cubic feet at 3379 feet.

TABLE 2.—*Lower Devonian and Deeper Wildcat Drilling Operations in Southwestern Pennsylvania during* 1943

County	Township	Name of Well	Elevation, Ft.	Depth, Ft.				Result	Remarks
				Tully	Onondaga	Oriskany	Total		
Beaver	Ohio	Cunningham	1,155		4,650[1]	4,846	4,862	Salt water. Abandoned	4100 S.W. at 4846 ft.
Beaver.........	Economy	Zladovich National Supply Co.	767					Drilling	
Butler..........	Mercer	Hockenberry	1,306		4,710[1]	4,825–4,846		Shut down at 6680 ft.	Lockport, 5934 to 6184 ft. Red Clinton, 6433; White Clinton, 5621; Queenston, 6636.
Westmoreland.	Ligonier	Beck	2,784	None	8,650[1] 8,695[2]	8,847	9,024	Abandoned	Downthrown side of fault. Deepest well in state
Westmoreland	Derry	Giffin No. 1	2,352	7,235–7,285 7,990–8,038			8,050	Abandoned	Downthrown side of fault. Did not reach Onondaga
Westmoreland.	Derry	Giffin No. 2	2,261						Moving in rig

[1] Limestone.
[2] Chert.

TABLE 3.—*Summit (Fayette County) Gas Pool in* 1943

Township	Name of Well	Elevation, Ft.	Depth, Ft.				Remarks
			Tully	Onondaga	Oriskany	Total	
Wharton....	Indian Creek No. 2	2,674	7,555 7,685	8,280[1] 8,312[2]	8,539	8,685	Dry hole. Second deepest well in state. Abandoned
Georges.....	Barton No. 4	2,451	6,439 6,526	6,985[1] 7,012[2]			Shut down. To be drilled deeper. 1250 M cu. ft. Gas in chert. In drag of fault
Georges.....	Walters	2,583	6,912–7,052	7,630[1] 7,660[2]		8,115	500 M cu. ft. in chert. Blew down to 59 M cu. ft. Not to Oriskany. Abandoned
S. Union....	Heyn No. 1	2,316					Drilling deeper, top Silurian 7150 ft. Sulphur gas, 150 M cu. ft. 7181 to 7346 ft.
S. Union....	Heyn No. 3	2,314				7,460	Drilled deeper. Did not reach Silurian. No additional gas

[1] Limestone.
[2] Chert.

Washington County activity was uniformly widespread but only two large wells were drilled, each with an initial of slightly over 2.7 million cubic feet. One of these was found in the Big Injun (Miss.) sand at a depth of 1416 ft. and rock pressure of 450 lb. in Fallowfield township, and the other in the Gantz (U. Dev.) sand at a depth of 2278 ft. and rock pressure of 580 lb. in Somerset township.

While activity in the vicinity of the Armbrust pool, Hempfield township, Westmoreland County, where only two wells of over one million cubic feet capacity were found during the year, has been dampened by dry holes, the number of wells drilled outside that area is nearly that of a year ago. Penn township, with a total of 21, leads in number of completed wells, none of which, however, were large.

Bell township had three wells of over one million cubic foot initial in several sands. A North Huntington township well had the largest open flow of the year in southwestern Pennsylvania, 7.877 million cubic feet, with 430 lb. rock pressure at a depth of 2410 ft. in the Hundred-foot (U. Dev.) sand. This well has settled to a delivery of slightly over 0.7 million cubic feet of gas into the line.

Deep-sand Development

Only three deep-sand (L. Dev.) wildcat wells were completed during the year and a fourth had to be abandoned after crossing over to the downthrown side of a fault with 755 ft. displacement. None of these wells were productive. One of them, in Mercer township, Butler County, was drilled primarily as a test of the Medina (L. Sil.) sands which were found nonproductive, as was the Oriskany (L. Dev.) sand and Newburg (M. Sil) horizon. It was located a short distance south of the southern edge of the Mercer County Oriskany no-sand area. A Trenton (M. Ord.) limestone or St. Peter (M. Ord.) sand test may be made of this well.

Another Oriskany well in Ohio township, Beaver County, found a head of 4100 ft. of brine 16 ft. in the sand. This was several miles down the south flank and 90 ft. lower than production in the South Beaver township, Beaver County, Oriskany pool.

The third well completed was situated on the Laurel Hill anticline about 2½ miles from a well drilled several years ago, in which good shows of gas accompanied by salt water were found in the Onondaga chert. Location was made as a result of detailed surface geological work, which was collaborated by several shallow cable-tool holes. However, the well ran nearly 1000 ft. low because a large fault was crossed. No showing was found. This well is the second deepest cable-tool hole in the Appalachian area.

Two wildcat wells are drilling in the Oriskany (L. Dev.) sand—one on a south-plunging nose, where there was formerly a good Hundred-foot sand oil pool in Economy township, Beaver County, and the other on the Chestnut Ridge anticline, Derry township, Westmoreland County, approximately 1500 ft. southeast of the well that was abandoned after the fault with 755 ft. displacement had been crossed.

Summit Pool

Activity in the Summit (Fayette County) pool reached its lowest ebb since its discovery, and both new wells completed were failures. However, a third well is shut down in the Onondaga (L. Dev.) chert with 1.25 million cubic feet of gas showing in that horizon. This is structurally the highest well drilled in the southern end of the Summit pool. Two wells were deepened; one failed to reach the Silurian and was dry, and the other is attempting to reach the Lockport (M. Sil.) dolomite or Medina (L. Sil.) sands. The latter found 150,000 cu. ft. of slightly sulphurous gas in the top of the Silurian at the same horizon at which gas was found a number of years ago in the deep well west of Ligonier in Westmoreland County.

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Oil and Gas Developments in the Rocky Mountain Region during 1943

By C. E. Shoenfelt* and Gail F. Moulton,† Members A.I.M.E.

Proven and developed oil reserves, and productive capacity increased during 1943 in the fields of the Rocky Mountain region. Oil production during the year was nearly 45 million barrels, or slightly less than in 1942. The rate of production at the start of 1944 was slightly less than at the start of 1943. Pipe-line projects scheduled for completion during 1944 should permit a substantial increase in the rate of production.

Wildcat exploration was more extensive in Montana during 1943 than in other states in the region. The results of wildcat drilling were unsatisfactory, although new oil fields were discovered on the Gebo, Little Buffalo Basin and Steamboat Butte structures of Wyoming, the Gage anticline of Montana, and the Clark Lake structure of Colorado. The area of the structures on which the discovery wells were drilled is known to be considerable, but further drilling is required to determine the importance of these fields. The most important increase in proven reserves resulted from the drilling to newly discovered deeper producing formations in the Elk Basin and other fields of the Big Horn Basin area of northern Wyoming.

Lack of a market and unfavorable prices for heavy black oils had prevented complete exploration of favorable areas in the Rocky Mountain region for many years. In particular, the effect on further exploitation of the Big Horn Basin area had been quite serious. The increased demands for all oils created by the war and an increase in price in February 1943, combined later with Government approval of construction of pipe lines from the Big Horn Basin area to the Billings and the Casper districts, provided a basis for undertaking a drilling program. The important additions to reserves were made by drilling in previously discovered fields. The newly discovered fields resulted from drilling on favorable structures which had been known for several years. A continuation of the favorable results obtained during 1943 seems possible only if further testing of the newly discovered fields is satisfactory and if drilling on less favorable known structures or geophysical prospects results in the discovery of new fields.

The amount of drilling in the Rocky Mountain states of Colorado, Montana and Wyoming, was about the same during 1943 as in 1942. However, owing to the fact that a number of wells of large potential production were completed in the Elk Basin field, the total initial production of the producing wells was nearly twice as great for 1943 as for 1942.

Explorational activity at the end of 1943 seemed to be directed to geophysical methods, which are required to discover structures hidden beneath the rocks of Tertiary age in the Powder River and other large sedimentary basins. It is in

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* Mr. Shoenfelt's plans to prepare the summary of oil and gas developments in the Rocky Mountain region could not be carried out because of illness followed by his death in April 1944. The junior author has prepared the following report from the annual Resume of Petroleum Information, Denver, Colorado, supplemented by information from other sources. Manuscript received at the office of the Institute May 21, 1944.

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TABLE 1.—*Oil and Gas Production in Rocky Mountain District*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
	COLORADO										
	OIL, BBL.										
1	Berthoud, *Larimer*	1925	510	66,137	2,078				1		
2	Boulder, *Boulder*	1902	400	664,131	4,677				15		
3	Clark Lake, *Larimer*	1943									
4	Florence, *Fremont*	1862	9,000	13,803,008	20,971				68		
5	Fort Collins, *Larimer*	1923	400	2,289,729	28,537				6		
6	Greasewood, *Weld*	1930	200	479,425	3,146				1		
7	Hiawatha, *Moffat*	1929	640	487,246	152,015				8		
8	Iles Dome, *Moffat*	1924	600	10,094,282	483,037				27		
9	Moffat (Craig)	1923		6,046,183	127,336				11		
10	Powder Wash, *Moffat*	1936	80	117,882	39,892				4		
11	Price, *Archuleta*	1934	200	1,880,499	251,208				9		
12	Rangely (Shale Oil), *Rio Blanco*	1919	320	1,574,265	296,969				25		
13	Rangely, *Rio Blanco*	1933		14,483	14,483				1		
14	Tow Creek, *Routt*	1924	200	1,831,820	46,884				9		
15	Walden, *Jackson*	1927	320	85,336	0				2		
16	Wellington, *Larimer*	1924	1,000	5,075,482	73,544				10		
17	Wilson Creek, *Rio Blanco*	1938	2,300	2,164,694	759,736				12		
	GAS, MILLIONS CU. FT.										
18	Berthoud, *Larimer*	1925	320						1		
19	Douglas Creek, *Rio Blanco*	1943							1		
20	Garcia, *Las Animas*	1927	640						16		
21	Hiawatha, *Moffat*	1928	3,180						13		
22	Model, *Las Animas*	1929	4,380						8		
23	Powder Wash, *Moffat*	1936	400						6		
24	Thornburg, *Rio Blanco*	1925	350						3		
	MONTANA										
25	Border, *Toole*	1930	450	1,117,716	21,076				27		
26	Cat Creek, *Petroleum*	1920	1,600	15,392,873	119,322				117		
27	Cedar Creek, *Fallow*	1936	80	17,588	0				2		
28	Cut Bank, *Glacier*	1932	38,000	36,857,970	5,327,207				786		
29	Devils Basin	1919		31,322	0				2		
30	Dry Creek, *Carbon*	1930	200	2,057,318	96,540				7		
31	Elk Basin (Light), *Carbon*	1916	140	1,051,127	13,645				20		
32	Elk Basin (Heavy), *Carbon*	1942		229,514	229,514				4		
33	Frannie, *Carbon*	1940	40	66,461	13,641				2		
34	Gage, *Musselshell*	1943		377	377				1		
35	Ingomar, *Rosebud*	1943					8,200	8,200	1		
36	Kevin-Sunburst, *Toole*	1922	45,000	43,991,835	1,817,851				1,209		
37	Lake Basin, *Stillwater*	1924	300	495,618	15,888				2		
38	Pondera, *Teton*	1927	1,600	6,418,690	211,862				151		
39	Sweetgrass Hills, *Toole*	1929	500	120,280	6,504				7		
40	Thorpe	1943		160	160				1		

[b] Footnotes to column heads and explanation of symbols are given on page 270.

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
COLORADO																
OIL, BBL.																
1				600			38.5	0.1	Hygiene, CreU	S H	20	2,920	20	A	LaNota (CreL)	4,031
2							38.6	0.2	Pierre, CreU	Sh		2,000		MF		3,100
3									Muddy, CreU	S				A	Sundance (Jur)	6,510
4							31.0	0.1	Pierre, CreU	H		2,200			Fountain (Pen)	
5							37.0	0.1	Muddy-Dakota, CreU Sundance, Jur	S S	18 14	4,535 5,063	25 139		Sundance (Jur)	5,206
6							42.0	0.1	Muddy-Dakota, CreU	S	9	6,645	35	A	Morrison (Jur)	7,040
7				850			36.9	0.1	Wasatch, Eoc	S		Sand lenses		D	Mesa Verde (CreU)	7,577
8							37.0	0.1	Sundance, Jur	S	9	3,295	20	D	Sundance (Jur)	3,454
9							41.0									
10				685			37.4	0.1	Wasatch, Eoc		Por	Sand lenses		D	Wasatch (Eoc)	5,878
11							40	0.1	Dakota, CreU	S		1,120	20	A	Dakota(?)	1,350
12							43	0.1	Mancus, CreU	Sh		600				
13							32.5		Weber, Pen, Mancos	S		5,750		A	Weber	7,137
14							35	0.1	Mancos, CreU	H				A	Gneiss	5,310
15							50	0.1	Muddy-Dakota, CreU	S	14	5,110	90	AF	Morrison (Jur)	5,258
16							37.4	0.1	Muddy-Dakota, CreU	S	12	4,480	20	A	Sundance (Jur)	4,992
17							46	0.1	Morrison, CreL	S		6,550	125	D	Sundance (Jur)	6,981
GAS, MILLIONS CU. FT.																
18				600				0.1	Hygiene, CreU	S		2,920	20		Lakota (CreL)	4,031
19									Dakota-Lakota, CreU	S		4,326		DF	Hermosa (PenL)	8,558
20				12				0.1	Benton, CreU	H		1,600		D	Fountain (Pen)	2,500
21				850				0.1	Wasatch, Eoc			Sand lenses		AF	Mesa Verde (CreU)	7,577
22				12					Santa Rosa, Tri	S	19	960	50	D	Fountain (Pen)	2,010
23				685				0.1	Wasatch, Eoc			Sand lenses			Wasatch (Eoc)	5,878
24				725					Dakota, CreU	S	15	2,200	30	D	Sundance (Jur)	3,110
MONTANA																
25							32 34		Koutenai, CreL	S, SH	14	2,470	15	MC	Devonian	3,890
26							49		Cat Creek, Cre	S		1,200		AF	Madison (Mis)	1,964
27							29.5		Madison, Mis	L		6,750			Devonian	
28							41		Cut Bank, Cre Koutenai, CreL	S	14	2,800	30	MC	Madison	3,160
29							24.7									
30							51		Claggett, Eagle, Frontier, Mowry, CreU; Cloverly, CreL	S		5,500			Tensleep	6,887
31							43		Frontier, CreU oil; Cloverly, CreL (gas)	S		1,000				
32							30.7		Tensleep, Pen	S		4,400	100	A	Tensleep	5,752
33							27.1		Tensleep, Pen	S		2,700		D		
34							28.2		Amsden, Pen	LS		5,965		D	Devonian(?)	7,495
35									Amsden, Pen	LS		3,910	120			5,814
36							34		Koutenai; CreL; Ellis, Jur; Madison, Mis	S L		1,400		D	Pre	4,710
37							44.1		Eagle-Frontier, Dakota, CreU	S		1,200	100	D	Madison (MisL)	6,002
38							34		Madison, MisL	L		1,975	10	T	Madison (MisL)	2,354
39							37 36		Koutenai, CreL; Ellis, Jur; Madison, MisL	S, L		1,400		D	Madison (MisL)	2,205
40																

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
										1943	
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned
	WYOMING										
41	Badger Basin, *Park*	1931	300	544,673	74,286				2		
42	Big Medicine Bow, *Carbon*	1935	800	4,267,745	228,557				4		
43	Big Muddy, *Converse*	1915	2,000	27,797,362	382,261				135		
44	Black Mt., *Hot Springs*	1925	300	295,805	9,410				8		
45	Byron, *Big Horn*	1906	2,950	9,511,219	2,002,036				24		
46	Circle Ridge, *Fremont*	1923		311,746	251,941				10		
47	Cole Creek, *Matrona*	1938	900	1,297,100	419,366				29		
48	Dallas-Derby, *Fremont*	1883	350	3,446,816	161,562				34		
49	Dewey Dome, *Weston*	1938		21,186	0				1		
50	Dutton Creek, *Carbon*	1927	150	323,000	16,770				3		
51	Elk Basin (Light), *Park*	1915	580	11,737,573	159,054				142		
52	Elk Basin (Heavy), *Park*	1942	3,000	2,212,418	2,203,962				25		
53	Ferris, *Carbon*	1918	200	566,670	6,149				2		
54	Frannie, *Park*	1928	500	7,755,768	989,655				32		
55	Garland, *Big Horn*	1930	2,000	5,407,857	201,360				10		
56	Gebo Dome, *Hot Springs*	1943			2,500						
57	Gooseberry, *Park*	1937	500	19,970	6,815				1		
58	Grass Creek, *Hot Springs*	1914	2,000	32,088,089	877,553				199		
59	Greybull, *Big Horn*	1907	640	346,730	0				1		
60	Hamilton Dome, *Hot Springs*	1913	2,000	6,487,234	504,077				33		
61	Hidden Dome, *Washakie*	1933	50	391,983	13,438				16		
62	Horse Creek	1942		11,545	11,545				2		
63	Hudson, *Fremont*	1914	340	2,411,602	91,925				35		
64	Iron Creek, *Natrona*	1922	120	31,626	3,346				4		
65	La Barge, *Sublette*	1923	950	8,650,674	626,638				142		
66	Lance Creek, *Niobrara*	1918	15,000	57,144,763	7,273,609				220		
67	Lost Soldier, *Sweetwater*	1915	450	22,512,549	1,894,983				48		
68	Mahoney Dome, *Carbon*	1930	250	1,436,248	288,931				10		
69	Maverick Springs, *Fremont*	1921	1,400	1,817,908	564,411				35		
70	Midway, *Natrona*	1930	200	175,886	0						
71	Mule Creek, *Niobrara*	1919		1,461,022	13,303				42		
72	Notches, *Natrona*	1923	400	328,672	116,848				4		
73	Oregon Basin, *Park*	1927	10,000	25,740,832	4,980,686				108		
74	Osage, *Weston*	1920	10,000	5,192,963	184,260				231		
75	Pilot Butte, *Fremont*	1916	300	1,209,444	466,281				8		
76	Quealy, *Albany*	1934	320	1,503,353	159,780				17		
77	Rex Lake, *Albany*	1923	200	294,934	23,574				3		
78	Rock Creek, *Carbon*	1918	1,300	22,622,320	910,921				39		

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil		Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift														
									WYOMING							
41							48		Frontier, CreU	S	Por	8,250	49	A		8,660
42							56.9		Sundance, Jur	S		5,200				
43							33.5		Wall Cr., Dakota, CreU	S		3,260				
44							24		Embar-Tensleep, Per, Pen	LS		2,900	135	A	Madison (MisL)	3,832
45							20		Embar-Tensleep, Per, Pen	LS	Cav, Por	5,400	130	AF		
46							23.7		Tensleep, Pen	S		600				
47							32.7		Lakota, CreL Shannon, CreU	S S	Por	8,019 4,550	100	A	Sundance (Jur)	8,708
48							23.2 -Dallas 22.3 -Derby		Embar-Tensleep, Per, Pen	LS	Cav, Por	700	150	A	Tensleep (Pen)	1,400
49							31		Leo Zone, Minnelusa, Pen	S	Por	2,294	40	A	Madison? (MisL)	2,890
50							33.6		Muddy, CreU	S		4,850	40		Sundance (Jur)	5,448
51							43		Frontier, CreU	S	Por	1,000	40	AF		
52							30.7		Tensleep, Pen	S		4,488			Tensleep (Pen)	5,581
53							36.3 42		Mowry-Dakota, CreU	S	Por	1,600	25	A	Embar (Per)	4,600
54							27.7 -L 17.6 -H		Tensleep, Pen	S	Por	2,770	100	AF	Madison (MisL)	3,013
55							22		Madison, Embar-Tensleep, Per-Pen	LS	Cav Por	3,600 3,000	300 100	AF	Cambrian	4,750
56							29		Embar, Per	LS		4,680	150	D	Tensleep	5,309
57							22		Madison, Embar-Tensleep, Per-Pen	LS	Cav, Por	5,669	50	A	Tensleep (Pen)	6,076
58							43 -L 19-24.7 -H		Embar-Tensleep, Frontier, CreU	S	Por	3,600 800	200 250	A A	Amsden (Per)	4,512
59							44.3		Grey Bull, CreU	S	Por	1,000	20	AF	Tensleep (Pen)	2,950
60							25.6 16.7		Embar-Tensleep, Per, Pen	LS, S		2,700	130	A	Tensleep (Pen)	2,886
61							40		Frontier, CreU	S	Por	1,500	15	A		
62							30.4									
63							23.3		Embar-Tensleep, Per-Pen	LS	Cav, Por	1,300	185	A		
64							29.5		Dakota, CreU	S	Por	650	25	A	Sundance (Jur)	1,633
65							32		Wasatch, Eoc	S	Por	650	150		Hilliard (CreU)	6,200
66							43.6		Leo Zone, Minnelusa, Pen Frontier, CreU	S S		5,500 175		D	Granite	6,434
67							32 -L 28.8 -H		Tensleep, Pen	S	Por	3,900	50	AF	Tensleep (Pen)	4,087
68							32		Tensleep, Pen	S	Por	4,600	160	A	Tensleep (Pen)	4,690
69							22		Embar, Per	L	Cav	1,450	50	A	Tensleep (Pen)	2,094
70							32.5		Frontier-Muddy, CreU	S	Por	5,200	60	A	Chugwater (Tri-Per)	6,689
71							31.5		Minnelusa, Pen Dakota-Lakota, Cre	S S		2,800 1,500	10 30	A	Madison (MisL)	3,047
72							21		Tensleep, Pen	S	Por	2,800	40	A	Tensleep (Pen)	2,918
73							21.6		Embar-Tensleep, Per-Pen	LS	Cav, Por	3,500	150	AF	Madison (MisL)	4,650
74							41.6		Newcastle, CreU	S	Por	220	10	ML	Minnelusa (Pen)	2,235
75							42		Tensleep, Pen Niobrara, CreU	S H	Fis Fis	6,184 800	100 15	AF	Madison ?	6,660
76							32.8		Muddy-Dakota, CreU	S	Por	3,260	60	A	Sundance (Jur)	4,207
77							35		Dakota, CreU	S	Por	3,800	50	A	Lakota (CreL)	3,930
78							37 -L 27.7 -Tensleep 21.6 -Madison		Sundance, Jur	S	Por	3,150	100	A	Embar	5,627

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c] To End of 1943	Oil Production Total, Bbl.[c] During 1943	Producing Days, 1943[d]	Gas Production, Millions Cu. Ft.[e] To End of 1943	Gas Production, Millions Cu. Ft.[e] During 1943	Number of Oil and/or Gas Wells[f] Completed to End of 1943	Number of Oil and/or Gas Wells[f] 1943 Completed	Number of Oil and/or Gas Wells[f] 1943 Abandoned
79	Spindletop, *Natrona*	1928	80	34,207	8,307				4		
80	Salt Creek, *Natrona*	1908	21,450	308,391,212	4,788,874				1,782		
81	Shoshone (Cody), *Park*	1929	540	107,268	28,339				2		
82	Sheep Creek, *Fremont*	1942	160	4,492	0				2		
83	South Casper Creek and Poison Spider, *Natrona*	1920	240	4,225,446	264,170				36		
84	Steamboat Butte, *Fremont*	1943		220,375	220,375				3		
85	Spring Valley	1903		101,593	0						
86	Teapot (Naval Res.), *Natrona*	1922		3,618,790	0						
87	Teapot (Outside Naval Res.), *Natrona*	1927		128,044	4,363				2		
88	Torchlight	1915		254,709	0				44		
89	Warm Springs, *Hot Springs*	1917	160	434,151	24,651				19		
90	Wertz, *Carbon*	1936-H 1921-L	640	8,276,457	2,064,645				23		

these areas that the hope of continuing discovery of important fields in the Rocky Mountain area must be realized, for structures in areas of outcrop of Cretaceous formations near the mountain uplifts generally are obvious and have already been tested. A number of projects looking to the geophysical exploration of large areas are reported and it is anticipated that the efficiency of the more commonly used geophysical methods in exploration work in the Rocky Mountain area will be demonstrated during 1944 and succeeding years.

The Office of Price Administration raised the price of various crudes of Wyoming black oil 15¢ per barrel in February 1943 and later in the year permitted increases in the price posted for heavy oils in other parts of the state.

The trend toward concentration of oil-producing properties in the hands of the larger oil companies, characteristic of other parts of the country, was also a feature of operations in the Rocky Mountain area. The Carter Oil Co. acquired four refineries and important producing and undeveloped leases in the Lance Creek, Elk Basin, and Cut Bank fields by purchase from the Yale Oil Corporation, and by purchase of the Minnelusa Oil Corporation and Santa Rita Oil and Gas Co. The Union Oil Co. of California entered into a contract to purchase the properties of the Glacier Production Co. with oil and gas leases, gasoline plant and refinery in the Cut Bank field. Barnsdall Oil Co. purchased a half-interest in the Husky Refining Co., whose properties include a refinery at Cody and oil production in fields in the Big Horn Basin.

COLORADO

Exploration in Colorado resulted in the discovery of one gas field and one oil field. Additional development in previously producing areas increased the production of two of the fields, but there were no developments of great importance.

Clark Lake.—Amerada Petroleum Company and Alder Oil Company's No. 1 Hartshorn, sec. 15, T. 9N., R. 68W., was

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
79							22		Sundance, Jur	S	Por	1,100	25	A	Tensleep (Pen)	2,705
80							37 27.7	L –H	Tensleep, Sundance, Frontier, CreU	S		2,750 3,970 1,535	70 190 75	D	Granite	5,400
81							18.6		Embar, Per	LS	Cav	4,300	24	A		
82							22.8									
83							21 15.3		Sundance, Jur Tensleep, Pen	S S	Por Por	1,400 2,600	35 150	A	Granite	4,119
84									Sundance, Jur	S		5,094	30	AF	Sundance (Jur)	5,228
85							48.3		Aspen, CreU	H		400	900	MC	Bear River (CreU)	2,065
86							35.2		Wall Creek Shale, CreU	H	Fis	2,900 1,200	40	AF	Frontier (CreU)	3,140
87							38.6									
88							45.6		Mowry, CreU	SH	Por	400	50	A		
89							21		Embar, Per	L	Cav	700	50	A	Tensleep (Pen)	4,246
90							21 58	H –L	Tensleep, Pen	S	Por	5,860	300	A	Tensleep	5,883

completed in the Muddy sand after plugging back from a total depth of 6510 ft., where it encountered water in the Sundance sand. This well had an initial production after the end of the year of 168 bbl. per day. The structure was discovered by use of reflection seismograph, as it has no surface expression.

Douglas Creek.—The Douglas Creek gas field, Rio Blanca County, was discovered by a well in sec. 5, T. 3S, R. 101W., having initial open flow of about 10 million cubic feet and was drilled jointly by Superior Oil Company of California, Continental Oil Co., and Union Oil Co. of California. This structure has been known for some time and is associated with the Rangely anticline, where oil production has been obtained for some years.

North McCollum.—Continental Oil Company's No. 5 Pollack, sec. 2, T. 9N., R. 79 W., extended the productive area ¾ mile. This well was completed in the Frontier sand of Cretaceous age at a depth of 5049 to 5080 ft. for an initial production of 192 bbl. of 46° gravity oil per day, together with 10 million cubic feet of carbon dioxide gas.

Rangely Field.—Production of oil from the Rangely field in Rio Blanca County, western Colorado, was first obtained from the Mancos shale of Cretaceous age, which outcrops in the field. This production began in 1919. Although most of the wells drilled during 1943 also obtained production in this zone, the development of production in deeper formations was the important feature of the year's activity. The large anticlinal structure indicated by outcrops appeared attractive for deeper drilling, and prior to 1933 gas wells with considerable open flows were completed in the Dakota sand at a depth of about 3000 ft. In 1933 the California Co. and associates drilled their No. 1 Raven in sec. 30, T. 2N., R. 102W., to a total depth of 7173 ft. Oil was discovered in the various zones in the Weber sand between 5750 and 6315 ft. in depth and the well was shut in. In 1943 the operators reopened the well and shot the Weber sand first with 650 qt. and then with 1200 qt. of nitroglycerin.

Since being put on production the well has averaged about 200 bbl. per day, flowing through a choke.

Wilson Creek Structure.—Two additional wells were drilled during the year in the Wilson Creek area of Rio Blanca County, finding production at depths below 6500 ft. and having an average initial production of 280 bbl. per day.

MONTANA

The discovery of oil in the Amsden formation on the Gage anticline, Musselshell County, was the most important development of 1943 in Montana. Drilling in other parts of the state in the main was disappointing, for neither important extensions to oil-producing areas nor new fields were discovered. Developments in eastern Montana in particular failed to provide encouragement for further exploration.

Gage Anticline.—Small oil production on the Gage anticline, Musselshell County, was obtained in Northern Ordnance, Inc.'s No. 1 Morris, sec. 15, T. 9N., R. 26E., at a depth of 5965 to 6100 ft., plugged back from 7495 ft. This well was drilled on leases subleased from the Carter Oil Co., whose exploration department had recommended the structure. Before the end of 1943 two additional wells had been started, in spite of the fact that the rate of production of the first well was hardly commercial.

Ingomar.—Gas was discovered in the Amsden formation on the Ingomar dome, Rosebud County, by Northern Ordnance, Inc.'s No. 1 Hill, sec. 2, T. 9N, R. 35E. Production was obtained at 3910 to 4030 ft. in a well plugged back from testing lower formations to a total depth of 5814 ft. This discovery is of undetermined importance and the gas is of poor quality, because of its high nitrogen content. One additional well started in the field was shut down at a shallow depth at the end of the year. The particular significance of the Ingomar and the Gage discoveries is the fact that strata of the typical Big Horn Basin geologic section have been found far to the north of any areas where they had previously been productive.

Kevin-Sunburst District.—Minor extensions were made to the Kevin-Sunburst district, the most important of which was on the west side of the field, where a well of The Texas Company in sec. 2, T. 34N., R. 3W., flowed 155 bbl. of oil per day after acid treatment. A new area of gas production discovered by Nadeau Brothers southwest of the Shelby gas field was followed by additional development around their No. 1 Russell, sec. 1, T. 31N., R. 3W. These and other discoveries of undemonstrated importance are typical results, which may be anticipated by drilling in a large area around this field. As is clearly shown by an outline of the producing area traced on a structure map of the Kevin-Sunburst field, the area of production is controlled by the character of the producing formations and not by the structure. Consequently, it is to be anticipated that further development in other presently nonproducing areas on this structure, which have been thought to be condemned because of the failure of wells drilled near by, will likewise prove them productive.

East Utopia.—The Texas Company's No. 1 State, sec. 10, T. 33N., R. 4E., discovered the East Utopia field by finding production in the Madison lime at a depth of 2579 ft. The initial production was 20 bbl. per day of 16° gravity oil. This was the only new field discovered in northern Montana during the year.

Elk Basin.—Drilling in the Montana portion of the Elk Basin field resulted in the completion during the year of four wells producing from the Tensleep sandstone at depths of approximately 5000 ft. and having an average initial production of 1200 bbl. per day. An area of some 800 to 1000 acres appears to be proven for production as a result of this development.

Cedar Creek Gas Field.—The Cedar Creek gas field was developed further by the drilling of six wells in Fallon County, having an average open flow of 1.3 million cubic feet per day. There were no important new developments in this portion of the state.

Exploration of Deeper Formations

Most wells drilled in the Rocky Mountain states have been abandoned if they failed to find production in or above the first 50 to 100 ft. of the Madison limestone. The expense of drilling through this hard formation, which may be 1000 ft. thick, or more, and the uncertainty of what would be found below, has usually caused the operator failing to find production to this depth to abandon his well. Activity in northern Montana during 1943 was unique in that a number of wells were drilled far into or through the Madison limestone. Most of these were reportedly situated on structures in the older rocks underlying the Madison, as determined by the use of reflection seismograph. These wells, which were situated in Pondera, Teton and Toole Counties, had not been successful in finding production in the deeper formations up to the end of the year, although at least one of them is reported to have encountered showings of oil and gas in strata somewhat below those previously tested in the vicinity. If favorable conditions are demonstrated for the Devonian or lower Mississippian formations by any of these wells, a new era of deeper drilling would be inaugurated for northern Montana.

WYOMING

Wyoming maintained its place as the leading oil-producing state of the Rocky Mountain region during 1943. The discovery of oil production in three new areas, and the discovery of oil in a deeper formation in a fourth field, together with the development of an extensive area of proven production for the Tensleep zone in the Elk Basin field, were the important features of the year's activity.

Gebo.—The Continental Oil Co. discovered oil in the Tensleep sand in its No. 1 Gebo Unit in sec. 23, T. 44N., R. 95W. Because of the low permeability of this formation and the presence of water in the lower part of it, satisfactory production could not be obtained from this zone. Tests indicated a maximum production of 100 bbl. per day of 17 A.P.I. gravity oil. The well was plugged back and completed in the Embar formation, which occurred between 4680 and 4900 ft., and after treatment through casing perforations with 1500 gal. of acid, had an initial production of 2400 bbl. per day of 29°A.P.I. gravity oil. The entire area included within the limits of this structure was unitized prior to the start of the well and it is expected that an orderly development program will follow. At the present time no estimate can be made of the size of the field, although the structure covers more than 1000 acres and the reported thickness of the producing zone exceeds 150 feet.

Steamboat Butte.—British American Oil Producing Company's No. 1 Tribal, sec. 5, T. 3N, R. 1W., was completed in the Sundance sand at 5094 to 5109 ft. for an initial production of 623 bbl. of oil per day of 30°A.P.I. gravity. This field is a short distance north of the Pilot Butte field and occurs on the same axis of folding.

Little Buffalo Basin.—The Little Buffalo Basin structure in Park County, Wyoming, has been established as a gas field since the completion of wells producing from the Frontier sand in 1914. A large part of the area was unitized for gas production with respect to the Frontier sand by the Federal Government about 10 years ago. Since 1928 there has been a small market for gas supplied by wells in this field and no further development took place until 1943.

Oil production was discovered by Goodstein et al. No. 1 Government, sec. 13, T. 47N., R. 100W., which was drilled to a total depth of 4965 ft., 180 ft. below the top of the Tensleep sandstone. At the end of the year the productivity of this well had not been determined, although preliminary swabbing tests indicated a production of 7 bbl. per hour. Stanolind Oil and Gas Co. was drilling a well on this structure in sec. 34, T. 46N., R. 100W.

Oregon Basin.—Oil production in the Oregon Basin field, Park County, Wyoming, was discovered by the Ohio Oil Co., whose well in sec. 8, T. 51N., R. 100W., was completed in 1926 with an estimated initial production of 1000 bbl. per day from the Embar formation. Subsequent drilling resulted in oil production from the Tensleep sandstone as well as from the Embar and a considerable capacity for oil production was established before drilling operations were stopped. Through most of the subsequent years only a small amount of oil was produced, because of a lack of market for the heavy black oil obtained.

In 1943 the productive area of the main portion of the Oregon Basin field was further developed by the completion of 22 oil wells at depths ranging from 3400 to 4500 ft., with an average initial production of 248 bbl. per day. In the south Oregon Basin field, Yale Petroleum Company's No. 4 Hancock, sec. 5, T. 50N., R. 100W., discovered oil in the Madison limestone and was completed for an initial production of 1440 bbl. per day of 18°A.P.I. gravity oil. This well was drilled completely through the Madison limestone and apparently found its best production in the lower 100 feet.

Elk Basin.—The most important contribution of 1943 to the proven reserves of the Rocky Mountain region resulted from the drilling of 21 wells to the Tensleep formation in the Elk Basin field, Park County, Wyoming. These wells had a reported total initial production of 36,600 bbl. per day, or an average of more than 1700 bbl. per day per well. The approximate size of this reserve might have been suspected from knowledge of the structure after the completion of the discovery well in the Tensleep in 1942, but it required extensive drilling to prove the reserves. Although the surface and previously producing formations at shallower depths had been known to be affected by numerous faults crossing the axis of the structure, indications are that the Tensleep is not greatly affected by faulting. Up to the end of the year the structural limits of production for the Tensleep sandstone had not been defined, but the range in elevation of the top of the Tensleep formation in the producing area had already been established as being at least 1500 feet.

Other Areas.—Drilling in the older producing areas outside of the Big Horn Basin district was largely of a routine nature and a few wells were completed in the Lance Creek, Salt Creek, Cole Creek, and other established fields. In general, prospecting for additional production in southeastern Wyoming was unsatisfactory during the year. Some further development of the Baxter Basin gas field took place, but attempts to discover new producing areas in the southwestern portion of the state likewise had unsatisfactory results.

SOUTH DAKOTA

The only important oil test reported for South Dakota for the year was Northern Ordnance Company, Inc.'s No. 1 Harding County School Land, sec. 1, T. 17N., R. 1E. This well was drilled to a depth of about 8000 ft. and on a drill-stem test of the Ordovician sands at 7980 ft. obtained a hole full of hot sulphur water. The results of the test are particularly important because the Camp Crook anticline, on which the well is situated, was generally considered one of the most promising structures of northwestern South Dakota. This is the second failure on the structure and tested all of the formations that could be presumed to have a chance of producing oil or gas.

Oil and Gas Developments in Tennessee in 1943

By Kendall E. Born*

Production of crude oil in Tennessee during 1943 was approximately 8200 bbl., slightly less than the 1942 production, and the lowest since 1934. Approximately 7200 bbl. was produced from the Mississippian limestone pools in Scott and Morgan Counties. Some half dozen wells in Clay, Fentress, and Pickett Counties, pumped intermittently, produced about 1000 barrels.

Table 1.—*Oil Production in Tennessee in* 1943

County	Number of Wells Pumped	Production, Bbl.	
		1942	1943
Scott and Morgan.........	22	7,656	7,2*xx*
Clay, Pickett, Fentress.....	7	1,*xxx*	1,*xxx*

Natural gas was marketed from wells in Morgan and Fentress Counties for consumption in the Sunbright and Jamestown areas, respectively. The Morgan County production was about 10,000,000 cu. ft. and approximately 8,000,000 cu. ft. was produced from the Jamestown gas field from six wells.

The production of oil by counties is shown in Table 1.

Developments

Thirteen wells were spudded during the year; three were drilling on Dec. 1, 1943. Of the nine completions, representing 10,488 ft. of hole, three were gas wells of commercial size although only one of them has been placed on the line. The completions are listed in Table 2. The distribution of tests according to physiographic divisions is given in Table 3.

Table 2.—*Oil and Gas Tests Drilled in Tennessee during* 1943

County	Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
Fentress....	3 miles SW. of Jamestown	1,358	Middle Mis	Black River (Ord)	Joe Young	Commercial gas 1160 to 1165 ft.
Fentress....	4 miles SW. of Jamestown	1,025	Middle Mis	Trenton (Ord)	Young & Brandon	Commercial gas well capped
Jackson....	1.6 miles N. of North Springs	215	Trenton (Ord)	Trenton (Ord)	Gervase Jones	Gas at 215 ft., for domestic use
Jackson....	5 miles S. of Gainesboro	1,189	Trenton (Ord)	Knox (Є-Ord)	Glenn Rose et al.	Dry in upper part of Knox dolomite
Macon.....	Red Boiling Springs	1,588	Lower Mis	Knox (Є-Ord)	R. A. Leslie	Dry Knox test
Putnam....	Buffalo Valley	265	Trenton (Ord)	Black River (Ord)	C. W. Thomas et al.	
Scott.......	5 miles NW. of Oneida	1,148	Pen	Middle Mis	Fred Conn et al.	Free oil at 990 to 995 ft.
Scott.......	5 miles NW. of Oneida	1,149	Pen	Middle Mis	Allen Borton et al.	
Scott.......	3 miles W. of Oneida	1,750	Pen	Lower Mis	Clock Oil Company	Commercial gas at 1635; well capped

Cumberland Plateau.—There were three completions in the northern part of

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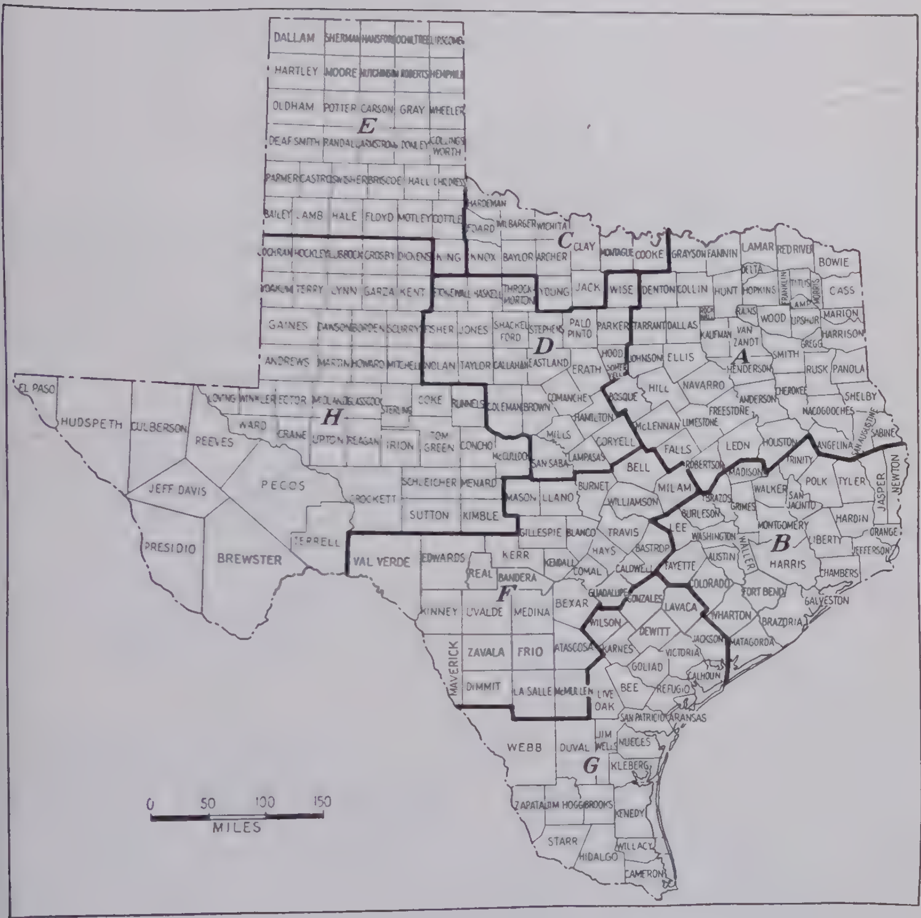
Cumberland Plateau. One of these, drilled 5 miles northwest of Oneida, in Scott County, encountered some free oil in a limestone of Chester age at 990 ft. This well has not been put on pump to determine its commercial possibilities. A gas well was completed 3 miles west of Oneida, in Scott County. The open flow is estimated at 1,000,000 cu. ft. and the rock pressure was 275 lb. The producing horizon is in the lower part of the Mississippian section at 1635 ft. This well is now capped, awaiting developments in the area. Late in the year, interest was focused on the Northern Cumberland Plateau, where some surface work was done. This area promises to be the most active in the state in 1944.

TABLE 3.—*Physiographic Distribution of Wells Drilled in Tennessee in* 1943

Physiographic Division	County	Wildcat	In Proven Fields	Oil Wells	Gas Wells
Northern Cumberland Plateau	Scott	1	2	0	1
Eastern Highland Rim	Fentress	1	1	0	2
	Jackson	2	0	0	0
	Putnam	1	0	0	0
Northern Highland Rim	Macon	1	0	0	0

Eastern Highland Rim.—Five completions on the Eastern Highland Rim included a commercial gas well in the Jamestown field, Fentress County. The others were relatively shallow tests, which were dry or near-dry holes.

Northern Highland Rim.—One test, at Red Boiling Springs, Macon County, was abandoned at 1588 feet.



TEXAS DISTRICTS

A. East and East Central (R.R.Comm. No. 5 and No. 6)
B. Gulf Coast (R.R.Comm. No. 3)
C. North (R.R.Comm. No. 9)
D. North Central (R.R.Comm. No. 7*B*)
E. Panhandle (R.R.Comm. No. 10)
F. South Central (R.R.Comm. No. 1)
G. South (R.R.Comm. No. 2 and No. 4)
H. West (R.R.Comm. No. 7*C* and No. 8)

Development and Production in East and East Central Texas in 1943

By D. V. Carter* and Dan C. Williams, Jr.†

During 1943 five oil fields and two gas-condensate fields were discovered in the East and East Central Texas district. The New Hope field, discovered by Tide Water-Seaboard in Franklin County, is the most important oil discovery since the Hawkins field in 1940. At the close of the year two oil sands were producing and two additional oil sands were being tested. The gas-condensate fields of Appleby in Nacogdoches County and the Stewards Mill field in Freestone County had only one producing well each. The Carthage field was extended 3 miles north and 4 miles west. Another well that was testing at the year end indicated a probable eastward extension of several miles.

The Quitman field, in Wood County, was the most active from the standpoint of drilling operations. Approximately 48 wells were completed during the year. The second and third most active fields were Hawkins field, Wood County, and Kildare field, Cass County, respectively. Wartime restrictions of material, together with manpower shortage and Federal spacing regulations, reduced the number of oil and gas-well completions from 265 in 1942 to 171 in 1943. This represents a drop of 35 percent, or approximately ⅓, enough to replace the 531 producing wells abandoned in the district during the year.

No changes were made in the price of crude oil in the district in 1943.

Production and Proration

The district produced 177,652,940 bbl. of condensate and oil during 1943. This represents an increase of approximately 11 per cent compared with the previous year.

The East Texas field, which is the largest and most important field in the district, had an annual production of 128,568,647 bbl. of oil, which is approximately 6.5 per cent more than the previous year, and represents 72 per cent of the district's production of condensate and oil for the year. The district had an estimated basic daily allowable of approximately 509,000 bbl. of oil on Dec. 31, 1943. The entire district produced approximately 30 per cent of the state's production for the year 1943.

The Hawkins field, Wood County, was operated 271 days during the year and with an average daily production of approximately 52,488 bbl. for the year. This field, which is the second largest in the district, produced 14,224,164 bbl. of oil during the year.

Changes in annual production in certain fields in the district can be attributed to their ability to produce at higher rates, the demand, and transportation facilities in the war effort.

The East Texas field showed an over-all decrease in reservoir pressure of 8.30 lb. during the year. Indications were that through the first quarter of 1944 the return of salt water to the reservoir was having a beneficial effect. It is hoped that, as more and more water is returned to the reser-

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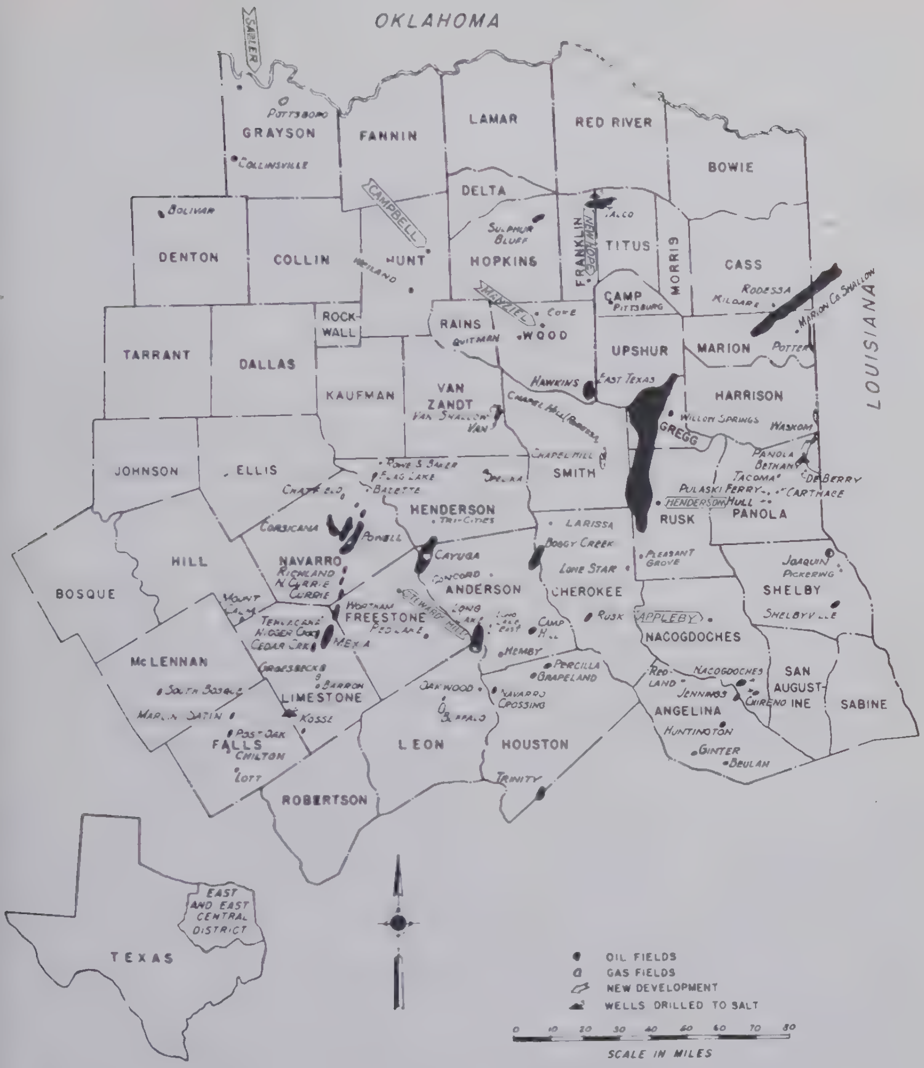

FIG. 1.—LOCATION OF OIL AND GAS FIELDS, EAST AND EAST CENTRAL TEXAS.
(Texas Railroad Commission Districts 5 and 6.)

TABLE 1.—*Oil and Gas Production in East and East Central Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
1	Appleby,[1] *Nacogdoches*	1943	20	*x*	*x*		*x*	*x*	1	1	0
2	Barron,[1] *Limestone*	1939	300	4,716	1,164		4,564	1,472	6	0	0
3	Bazette, *Navarro*	1939	100	235,936	47,843		*x*	*x*	9	0	0
4	Beulah (Lee-Tex), *Angelina*	1935	10	750	0	0	*x*	0	1	0	0
5	Boggy Creek, *Anderson, Cherokee*	1927	960	5,172,643	60,260		*x*	*x*	33	0	1
6	Bolivar, *Denton*	1937	600	14,911	465		*x*	*x*	10	0	3
7	Bosque, South, *McLennan*	1902	2,500	116,397	2,766		*x*	*x*	59	0	0
8	Buffalo,[2] *Leon*	1934	7,500	20,366 17,387	4,744 0		9,971	2,379	10	0	0
9	Camp Hill, *Anderson*	1935	200	289,030	0	0	*x*	0	10	0	0
10	Campbell, *Hunt*	1943	80	25,470	25,470		*x*	*x*	2	2	0
11	Carthage,[1,5] *Panola*	1936	8,000	440,314	182,882		26,419	11,334	26	8	0
12	Cayuga,[2] *Anderson, Henderson, Freestone.*	1934	9,700	2,132,543 29,118,028	466,529 3,387,440		148,014	23,931	336	0	10
13	Cayuga (Trinity),[2] *Anderson*	1938	40	521,045 27,471	49,247 5,435		24,991	2,554	6	0	0
14	Cedar Creek, *Limestone*	1927	30	330,600	0	0	*x*	0	14	0	0
15	Chapel Hill,[2] *Smith*	1938	10,000	1,713,570 1,357,758	611,003 679,655	249	29,204	11,361	66	11	1
16	Chatfield,[1] *Navarro*	1905	150	0	0	0	4,750	0	15	0	0
17	Coke, *Wood*	1942	1,200	540,107	486,924	261	38	34	30	0	0
18	Collinsville, *Grayson*	1938	100	35,770	718		0	0	2	0	1
19	Concord, *Anderson*	1942	20	15,143	3,534	249	*x*	*x*	1	0	0
20	Corsicana,[6] *Navarro*	1895	6,710	14,718,264	127,206		*x*	*x*	1,442[6]	1	3
21	Currie,[7] *Navarro*	1921	475	6,976,343	35,656		0	0	55	0	0
22	DeBerry, *Panola*	1926	100	29,166	0	0	*x*	0	22	0	0
23	East Texas,[2] *Cherokee, Gregg, Rusk, Smith, Upshur.*	1930	136,000	13,216 1,960,512,093	494 128,568,647	256	737,608[8]	45,585[8]	27,387	0	383
24	Flag Lake, *Henderson*	1937	405	576,372	36,642	249	*x*	*x*	26	1	2
25	Ginter, *Angelina*	1936	60	42,284	4,920	249	*x*	*x*	4	0	0
26	Grapeland,[2] *Houston*	1936	6,000	6,769,400 136,100	1,434,662 400		36,501	10,433	42	0	1
27	Groesbeck, *Limestone*	1913 1924 1941	*x* *x* 10	*x* *x* 3,257	*x* *x* 981		*x* *x* 4,032	*x* *x* 2,725	30 5 1	0 0 0	0 0 0
28	Hawkins,[2] *Wood*	1940	8,500	15,455 21,122,707	3,308 14,224,164	271	8,846	5,475	407	31	6
29	Hemby (Elkhart),[1] *Anderson*	1938	100	4,012	0		1,162	*x*	2	0	0
30	Henderson,[2] *Rusk*	1943	40	1,538 10,107	1,538 10,107	110	43	43	2	2	0
31	Huntington, *Angelina*	1936	100	14,463	492		*x*	*x*	12	0	0

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[b] Footnotes to column heads and explanation of symbols are given on page 270.
[1] Condensate field.
[2] Condensate and oil field, upper figure condensate production, lower figure oil production.
[5] Includes Hull and Pulaski Ferry.
[6] Includes Mildred, Angus-Edens, Hodge, Burk-Rice, Oil Ridge and Old Powell Shallow. Number of completions is approximate.
[7] Includes North Currie.
[8] Includes estimate of gas produced with oil and gas produced from gas wells.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1043		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[p]	Productive Thickness, Avg. Ft.[m] Net	Structure[o]	Name	Depth of Hole, Ft.
1	0	0	1	x	x		51.7	x	Travis Peak, CreL	S	x	8,610	30	A	Travis Peak	9,295
2	0	0	6	2,659	x		61	x	L. Glen Rose, CreL	L	15	5,584	25	AF	Travis Peak	6,051
3	0	8	0	1,300	x		42	x	Woodbine, CreU	S	23	2,992	15	AF	Woodbine	3,008
4	0	0	0	x	x		24	x	Queen City, Eoc	S	x	2,045	5	ML	Carrizo	2,324
5	0	16	0	1,680	x		38	x	Woodbine, CreU	S	25	3,632	34	DS	Fredericksburg	4,648
6	0	1	0	x	x		40	x	Cisco, Pen	SL	x	1,630	25	AF	Ellenburger	2,530
7	0	35	0	x	x		41	x	Basal Walnut, CreL	L	x	450	3	AF	Trinity	1,800
8	0	0	9	2,502[3] 2,620[4]	x x		48 25	x	Woodbine, CreU	S	20	5,273 5,634	22[3] 44[4]	D	Washita, CreL	6,300
9	0	0	0	1,950	x		41	x	Sub-Clarksville (Eagle Ford) Woodbine, CreU	S	x	5,054	5	AF	L. Glen Rose	8,383
10	0	2	0	1,830	x		32	x	Paluxy, CreL	S	15	4,350	10	AF	Glen Rose	4,800
11	0	0	23	x	x		55 64 61	x	L. Glen Rose, CreL L. Glen Rose, CreL L. Glen Rose (Pettit), CreL	OL L OL	19 23 x	4,984 5,930 5,825	20 10 x	MC D MC	Travis Peak	6,596
12	128	140	50	1,750	1,238	C	63 29	x	Woodbine, CreU	S	25	3,680	Gas 54 Oil 24	AF	Trinity	9,085
13	1	0	5	3,525	2,500	C	57 32	x	L. Glen Rose, CreL	L	20	7,600	10	AF	Trinity	9,085
14	0	0	0	x	x		37	x	Woodbine, CreU	S	25	2,885	10	AF	Woodbine	3,310
15	42	6	17	2,574 3,700 4,000	x x x		74 63 43	x x x	Paluxy L. Glen Rose (Rodessa), CreL L. Glen Rose (Pettit)	S OL OL	23 135 10	5,600 7,400 8,000	50 25 24	A	Travis Peak	8,600
16	0	0	0	250	x		Gas	x	Corsicana (Wolfe City) CreU	S	x	880	13	A	Woodbine	3,057
17	24	6	0	2,705	2,693		27	2.3	Paluxy, CreL	S	21	6,300	55	A	Travis Peak	8,900
18	0	1	0	x	x		29	x	Strawn, Pen	S	x	3,848	20	ML	Strawn	4,219
19	0	1	0	1,620	x		12	x	Woodbine, CreU	S	25	4,522	10	D	CreL	5,217
20	0	607	0	x	x		32 27	x	Nacatoch (Wolf City) CreU	S	x	800	12 20	AF	Woodbine	3,570
21	0	14	0	x	x		40	x	Woodbine, CreU	S	22	2,930	20	AF	Woodbine	3,646
22	0	0	0	757	x		46	x	Blossom, CreU	S, Sh	x	1,990	x	ML	Blossom	2,125
23	16,567	8,214	4	1,620	1,012		58 39	x	Woodbine, CreU	S	25	3,632	35	S[17]	Paluxy	5,020
24	0	11	0	1,394	x		45	x	Woodbine, CreU	S	23	3,075	5	AF	Travis Peak	6,518
25	0	4	0	x	x		21	x	Carrizo, Eoc	S	x	2,186	10	ML	Wilcox	2,265
26	0	0	33	2,535	x	C	63 43	x	Woodbine, CreU	S	25	5,976	25	A	Woodbine	6,300
27	0 0 1	0 0 0	0 0 0	275 875 x	x x x		Gas Gas 41	x x x	Nacatoch Woodbine, CreU L. Glen Rose (Pettit) CreL	S S L	25 20 x	710 2,945 5,685	40 15 x	AF AF	Woodbine L. Glen Rose (Pettit)	3,208 5,796
28	369	25	1	1,990[9]	1,872		25	1.6	Sub-Clarksville Woodbine, CreU	S S	x 30	3,910 4,475	Gas 80 Oil 160	AF	Paluxy	6,535
29	0	0	1	2,200	x		59	x	Woodbine, CreU	S	25	5,409	x	AD	Woodbine	5,487
30	2	0	0	1,900	x		43	x	L. Glen Rose (Pettit) CreL	L	x	7,250	14	A	Pettit	7,494
31	0	1	0	x	x		24	x	Queen City, Eoc	S	x	1,458	8	ML	Mount Selman	1,490

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[3] South dome.

[4] North dome.

[9] Corrected to 4075 ft. subsea.

[17] S indicates Shoreline.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
32	Joaquin,[1,10] *Shelby*	1931	6,000	204,874	49,039		44,029	15,753	27	0	7
33	Kildare,[2] *Cass*	1942	1,300	3,598 780,076	3,598 647,394		282	282	30	20	0
34	Kosse, *Limestone*	1922	10	33,000	0	0	*x*	*x*	1	0	0
35	Larissa, *Cherokee*	1942	40	13,052	11,338		*x*	*x*	1	0	0
36	Lone Star, *Cherokee*	1938	100	74,771	22,910		*x*	*x*	4	1	0
37	Long Lake,[2] *Anderson, Freestone, Leon*	1933	10,000	5,686,953 7,048,045	1,127,545 1,378,889	249	97,446	15,617	238	16	3
38	Long Lake, East, *Anderson*	1941	300	324,878	142,355	249	*x*	*x*	12	0	0
39	Lott, *Falls*	1937	*x*	31,899	0	0	*x*	*x*	5	0	3
40	Manziel, *Wood*	1943	400	80,568	80,568		*x*	*x*	10	10	0
41	Marion County (shallow)	1939	670	339,821	52,909		*x*	*x*	45	0	1
42	Marlin-Satin, *Falls*	1931	10	12,830	0	0	*x*	0	2	0	0
43	Mexia, *Limestone*	1920	3,920	98,904,197	514,136		*x*	*x*	573	0	15
44	Mexia (shallow),[1] *Limestone*	1912	4,094	0	0	0	20,200	*x*	50	0	0
45	Mount Calm, *Hill*	1929	*x*	27,991	0	0	*x*	0	2	0	0
46	Nacogdoches,[11] *Nacogdoches*	1865	1,000	436,194	1,607		*x*	*x*	50	0	0
47	Navarro Crossing,[2] *Houston*	1938	3,450	2,375 811,816	0 86,938	249	11,414	1,314	31	0	1
48	New Hope, *Franklin*	1943	120	118,604	118,604	207	14 27	14 27	3[12] 3[12]	3[12] 3[12]	0 0
49	Nigger Creek, *Limestone*	1926	170	2,999,466	0	0	*x*	0	75	0	0
50	Oakwood,[2] *Leon*	1939	1,000	231 14,331	0 0	0	51 *x*	0 0	6	0	0
51	Opelika,[2] *Henderson*	1937	7,000	4,882,719 19,314	1,584,106 0	0	34,330	11,748	14	0	1
52	Panola (Bethany),[2,10] *Panola*	1921	23,000	50,585 70,336	17,386 6,425		158,939	3,935	355	0	12
53	Percilla,[2] *Houston*	1937	200	1,720 29,551	920 0	0	839	32	3	0	0
54	Pickering, *Shelby*	1941	20	948	0	0	*x*	*x*	1	0	1
55	Pittsburg, *Camp*	1940	1,400	284,160	143,427		*x*	*x*	9	3	0
56	Pleasant Grove, *Rusk*	1941	200	145,632	67,864	249	*x*	*x*	8	0	1
57	Pleasant Grove (shallow), *Rusk*	1941	40	17,011	6,627	249	*x*	*x*	1	0	0
58	Post Oak (Chilton), *Falls*	1922	100	178,983	0	0	*x*	0	26	0	0
59	Potter (Caddo),[10] *Marion*	1905	980	7,727,134	21,796		*x*	*x*	78	0	1
60	Pottsboro, *Grayson*	1928	20	12,804	999		*x*	*x*	15	0	0
61	Powell,[14] *Navarro*	1923	2,600	112,248,647	508,132		*x*	*x*	770	4	1
62	Quitman, *Wood*	1942	2,100	650,564	647,484	330	*x*	*x*	49	48	0
63	Redland, *Angelina*	1939	10	60	0	0	*x*	0	1	0	0
64	Red Lake,[2] *Freestone*	1934	3,000	1,916 1,605	101 0		2,090	96	3	0	1
65	Richland, *Navarro*	1924	440	6,680,167	10,951		*x*	*x*	101	0	0
66	Rodessa (Dees-Young),[2,10] *Cass*	1935	8,260	31,084,313[15]	1,284,071[15]		117,485	8,167	298	0	18

[10] Field extends into Louisiana.

[11] Includes Chireno and Jennings field.

[12] Dual oil completions.

[14] Includes shallow production discovered and produced since 1923 in the Powell Woodbine producing area.

[15] Production by horizons estimated. Includes distillate production.

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg. End 1943		Gravity A.P.I. at 60 F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
32	0	0	10	2,550	x	C	48	x	Upper Glen Rose, CreL	L	x	4,097	10	D	Glen Rose	5,138
									Lower Glen Rose, CreL	L	x	5,070	30			
33	26	3	1	2,750	x		41	x	L. Glen Rose (Gloyd) CreL	L	16	5,973	25 15	AF	L. Glen Rose (Dees-Young)	6,205
34	0	0	0	x	x		32	x	Unknown	x	x	x	x	Crev	Glen Rose	6,056
35	1	0	0	x	x		48	x	Lower Glen Rose (Pettit), CreL	OL	P	10,163	x	AD	Travis Peak	10,604
36	0	2	0	1,375	x		35	x	Woodbine, CreU	S	x	4,006	4	AF	Woodbine	4,015
37	112	28	65	2,440	2,113	C	63 41	x	Woodbine, CreU	S	25	5,170	24 8	A	Trinity	9,966
38	10	2	0	x	x		43	x	Woodbine, CreU	S	24	5,335	8	D	Woodbine	5,417
39	0	0	0	x	x		29	x	Buda, U. Washita, CreL	DL	x	1,250	10	AF	Edwards	1,500
40	7	3	0	x	x		34	x	Paluxy, CreL	S	x	6,244	15	AF	Travis Peak	8,768
41	0	37	0	x	x		42	x	Tokio, CreU	S	x	2,336	10	A	Tokio	2,346
42	0	0	0	x	x		34	x	Buda, CreL	L	20	1,000	20	AF	Glen Rose	1,429
43	0	193	0	x	x		35	x	Woodbine, CreU	S	25	3,000	50	AF	CreL or older	8,847
44	0	0	0	276	x		Gas	x	Nacatoch, CreU	S	25	710	40	AF	CreL or older	8,845
45	0	0	0	x	x		31	x	Austin Chalk, CreU	C	x	607	8	F	Travis Peak	3,398
46	0	38	0	x	x		23	x	Weches, Eoc	S	x	80	x	ML	CreL	5,484
47	16	5	1	2,670	2,570		41 37	x	Woodbine, CreU	S	24	5,750 5,874	Gas 31 Oil 7	DF	Woodbine	5,968
48	3[12]	0	0	3,425	3,425		43	x	Bacon Lime, (Rodessa)	OL	15	7,281	16	A	Travis Peak	8,089
	3[12]	0	0	3,523	3,411		48	x	Pittsbg (Trav. Pk.) CreL	S	13	7,900	50			
49	0	0	0	x	x		40	x	Woodbine, CreU	S	25	2,820	15	AF	Woodbine	3,509
50	0	0	0	x	x		36	x	Woodbine, CreU	S	x	5,838	3	D	Woodbine	5,913
51	0	0	12	3,845	x		59		L. Glen Rose (Rodessa) CreL	LS	19	8,170	40	AF	L. Glen Rose (Pettit)	9,740
				x	x		39	x	U. Glen Rose, CreL			7,195				
52	0	4	52	x	x		60 28	x	Various,[13] CreU, CreL	S, L	x	1,100	40	A	Salt	11,303
53	0	0	1	x	x		41	x	Woodbine, CreL	S	x	5,932 5,665	Gas 6 Oil 5	A	CreL, DelRio	6,634
54	0	0	0	x	x		40	x	Nacatoch, CreU	S	x	1,475	20	ML	Washita	3,343
55	0	9	0	3,408	2,300		39	x	Pittsburg (Travis Peak) CreL	S	16	7,948	35	D	Travis Peak	8,551
56	3	4	0	x	x		40	x	Woodbine, CreU	S	20	4,055	5	F,S[17]	Woodbine	4,372
57	0	1	0	x	x		35	x	Nacatoch, CreU	S	x	2,910	25	F,S[17]	Woodbine	4,372
58	0	0	0	x	x		33	x	Buda, CreL	L	x	1,025	10	AF	Trinity	3,567
59	0	27	0	x	x		40	x	Nacatoch Tokio, CreU	S	x 20	1,025 2,300	x 15	A	CreL (Tokio)	2,400
60	0	1	0	300	x		39	x	Trinity (Basal) CreL	S	x	830	8	MU	Ordovician or older	6,004
61	0	152	0	800	x		38	x	Woodbine, CreU	S	25	2,925	40	AF	Trinity	6,506
62	44	4	0	2,742	2,623		43	1 1	Paluxy, CreL	S	21	6,200	35	AD	Paluxy	6,645
63	0	0	0	x	x		23	x	Wilcox, Eoc	S	x	1,021	8	ML	Wilcox	1,032
64	0	0	2	2,102	x		x	x	Woodbine, CreU	S	20	4,850	25	AF	Woodbine	5,002
65	0	4	0	x	x		38	x	Woodbine, CreU	S	25	2,975	20	AF	Glen Rose	5,414
66	23	179	9	2,700	1,376		43	x	L. Glen Rose (Dees Young), CreL	L	17	5,794	25	AF		

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[13] Nacatoch 1100 ft. gas; Buckrange 1700, oil; Barlow 2300, gas; Adams 2650, gas; Tiller (Paluxy) 2300, gas; Werner 3600, gas; Jeter (Glen Rose) 5700, gas; Pettit, gas.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943	Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
										1943	
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned
67	Rodessa (Hill-Gloyd),[2,10] *Cass*	1936	11,650	9,484,947[15]	358,528[15]		43,040	2,685	89	0	9
68	Rodessa (Hill-Henderson-Gloyd),[2] *Marion.*	1937	11,650	13,027,924[15]	531,278[15]		54,407	9,261	181	0	23
69	Rodessa[2,10] total		31,560	53,597,184[15]	2,173,877[15]		214,932	20,113	568		50
70	Rowe and Baker, *Henderson*	1939	80	82,412	0	0	*x*	0	4	0	3
71	Rusk, *Cherokee*	1934	200	261,134	0	0	*x*	0	5	0	0
72	Sadler, *Grayson*	1943	20	166	166		*x*	*x*	1	1	0
73	Shelbyville, *Shelby*	1917	50	16,539	1,628		*x*	*x*	2	0	0
74	Sulphur Bluff	1936	855	11,084,850	1,509,342	249	*x*	*x*	73	0	0
75	Tacoma, *Panola*	1933	40	15,750	0	0	*x*	0	3	0	0
76	Talco, *Franklin, Titus*	1936	7,850	66,848,167	9,219,557		*x*	*x*	821	0	17
77	Tehaucana, *Limestone*	1940	60	46,527	8,387	249	*x*	*x*	8	0	0
78	Tri-Cities,[1] *Henderson*	1941	2,560	61,608	27,420		160	76	4	3	0
79	Trinity, *Houston*	1934	120	2,047,826	151,918	249	*x*	*x*	20	0	0
80	Van (deep), *Van Zandt*	1929	4,520	139,112,864	6,194,029	249	*x*	*x*	582	0	0
81	Van (shallow), *Van Zandt*	1933	200	353,527	21,162		*x*	*x*	40	1	0
82	Van, Total		4,720	139,466,391	6,215,191				622	1	
83	Waskom,[2,10] *Harrison*	1924	7,280	382,414 116,527	163,925 12,428		124,389	10,025	248	0	0
84	Weiland, *Hunt*	1942	250	135,689	112,082	331	*x*	*x*	7	1	0
85	Willow Springs,[2] *Gregg*	1938	6,500	462,882 2,065	205,492 0		31,683	10,678	10	0	0
86	Witherspoon,-McKie, *Navarro*	1915	400	810,495	0	0	*x*	0	85	0	0
87	Wortham,[16] *Freestone*	1924	715	23,071,114	132,183		*x*	0	341	0	2
88	Grand total		336,964	23,378,050 2,579,159,848	5,935,103 171,717,837		1,776,968	207,036	35,498	171	531

[16] Wortham Shallow discovered in 1912 included with Wortham.

voir in this field, the pressure can be practically stabilized. At the end of 1943 approximately 306,811 bbl. of salt water per day was being returned to the reservoir through the 64 injection wells in the East Texas field. Approximately 72 per cent of the salt water produced in the field was being returned to the reservoir in December 1943.

The only important change in Railroad Commission orders for the fields in the district was the order permitting East Texas field operators to transfer to other companies or individuals bonus allowable received for injecting salt water.

CONSTRUCTION OF OIL PIPE LINES

Approximately 112¼ miles of pipe line was constructed in the district during the year and only 44 miles was removed. Table 5 shows the pipe-line work during the year 1943.

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TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil		Gas	Initial	Avg., End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift														
67	15	28	8	2,700	702	P	42	*x*	L. Glen Rose (Hill-Gloyd), CreL	S, L	16	5,914	20	AF		
68	35	61	15	2,677	1,399		42	*x*	L. Glen Rose (Hill-Henderson-Gloyd) CreL	S, L	15	6,044	20	AF		
69	73	268	32												Salt, CreL or older	11,484
70	0	0	0	*x*	*x*		32	*x*	Woodbine, CreU	S	20	3,140	6	AF	Woodbine	3,149
71	0	0	0	*x*	*x*		42	*x*	Woodbine, CreU	S	20	5,120	10	MU	Woodbine	5,302
72	0	1	0	*x*	*x*		25	*x*	Strawn, Pen	S	*x*	7,160	10	M	Simpson	8,403
73	0	1	0	*x*	*x*		38	*x*	Blossom, CreU	S, L	*x*	3,196	10	ML	Georgetown	3,520
74	0	73	0	1,900	*x*		23	*x*	Paluxy, CreL	S	25	4,487	36	AF	Glen Rose	6,600
75	0	0	0	*x*	*x*		46	*x*	Blossom, CreU	S	*x*	2,073	10	ML	Blossom	2,302
76	14	709	0	1,920	*x*		21	*x*	Paluxy, CreL	S	20	4,200	35	AF	Salt	9,048
77	0	3	0	*x*	*x*		21	*x*	Woodbine, CreU	S	*x*	2,640	10	AF	Georgetown	2,825
78	0	0	4	3,650	*x*		60	*x*	L. Glen Rose (Rodessa) CreL	L	*x*	7,608	20	A	Travis Peak	8,474
79	0	16	0	870	*x*		24	*x*	Carrizo, Eoc	S	25	1,987	25	Ds	Wilcox	5,500
80	321	241	2	1,230	1,078		34	*x*	Woodbine, CreU	S	*x*	2,682	129	AF	Travis Peak	7,501
81	0	31	0	*x*	*x*		31	*x*	Nacatoch, CreU	S	*x*	1,200	20	AF	Travis Peak	7,501
82	321	272	2													
83	1	16	0	*x*	*x*		35	*x*	Nacatoch, CreU	S	*x*	800	15–40	A	Travis Peak	6,490
				2,268	2,125		59	*x*	Blossom, CreL	SH	15	*x*				
				2,660	2,217		59	*x*	Glen Rose, CreL	L	12	6,282				
84	7	0	0	1,242	*x*		36	*x*	Woodbine, CreU	S	33	2,750	14	AF	Eagle Mills	9,523
85	0	0	7	3,468	*x*	C	*x*	*x*	L. Glen Rose (Rodessa)	OL	*x*	6,768	Gas 2	D	Cotton Valley	10,284
							57		L. Glen Rose (Pettit) CreL			7,244	Gas 35			
							38		L. Glen Rose (Pettit)			7,298	Oil 10			
86	0	0	0	*x*	*x*		19	*x*	Nacatoch, CreU	S	14	825	19	AF	Woodbine	3,480
87	0	30	0	*x*	*x*		29		Nacatoch	S	*x*	1,361	6	AF	Glen Rose	4,825
							37	*x*	Woodbine, CreU	S	25	2,990	35			
88	17,775	10,998	339													

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TABLE 2.—*Summary of Drilling Operations in East and East Central Texas*
DISCOVERIES, EXTENSIONS, AND IMPORTANT WILDCATS DRILLED DURING 1943

Line No	County	Drilled by	Well Number and Farm	Survey	Producing Formation	
					Name	Completion Depth, Feet
1	Bowie	P. D. Bowlen et al.	1, A. L. Simms	H. G. Williams		
2	Dallas	J. F. Lucey & S. A. Guiberson, Jr.	1, D. H. Moyar	Thos. Johnson No. 678		
3	Franklin	Tide Water-Seaboard Oil Co.	1, A. J. Bacon	John Maximillian	Rodessa Travis Peak	7,295 7,902
4	Freestone	Carter-Gregg Oil Co.	1, M. L. Steward	James James	Woodbine	4,001
5	Grayson	Denver Prod. & Ref. Co.	1, R. H. Jewell	William Allen	Strawn	7,160
6	Hunt	Humble Oil & Ref. Co.	1, Jessie A. Rutherford	Samuel Lindsey		
7	Hunt	Humble Oil & Ref. Co.	1, F. F. Graham	William Elam		
8	Hunt	Stanolind Oil & Gas Co.	1, H. C. Tilson Heirs	Chas. C. Dale	Paluxy	4,358
9	Kaufman	Sun Oil Co.	1, J. M. Rutledge	E. Parsons		
10	Nacogdoches	The Texas Co.	1, G. W. Strahan	M. J. Ariola	Travis Peak	8,610
11	Panola	W. C. Feazel et al.	1, H. C. Jordan	A. Moorman	Upper Pettit Lower Pettit	5,778 5,944
12	Panola	Union Producing Co.	1, Cash Black	C. Black	Upper Pettit	5,695
13	Rusk	American Liberty Oil Co. & Beacon Oil & Ref. Co.	1, J. H. Allen	Taylor Brown	Pettit	7,250
14	Smith	Patrick & Tyrell Drill. Co.	1, C. L. Wycliff	Samuel Leeper		
15	Wood	B. B. Orr	1, J. C. Rainwater	Jason Sherman		
16	Wood	Plains Production Co.	1, Mit Cox	Joseph Simkins		
17	Wood	Jackson & Fisher	1, O. M. McCorley	H. Anderson No. 274		
18	Wood	Bobby Manziel et al.	1, W. F. Bailey	S. Burch	Paluxy	6,319

Line No.	Deepest Horizon Tested	Total Depth, Ft.	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.	Gas, Thousands Cu. Ft.		Casing	Tubing	
1	Smackover	8,987						Dry hole
2	Paleozoic	4,504						Dry hole
3	Travis Peak	8,090	165 181		6/64 9/64	840 940	750 700	Discovery well, New Hope field, dual completion Discovery well, New Hope field, dual completion
4	Woodbine	4,048	50	25,000	1/4	1,420	1,400	Discovery well, Stewards Mill field
5	Ellenburger	8,403	35					Discovery well, Sadler field
6	Paleozoic	7,483						Dry hole
7	Eagle Mills salt	9,523						Dry hole
8	Paluxy	4,451	121		Pump			Discovery well, Campbell field
9	Smackover	10,057						Dry hole
10	Travis Peak	9,295	28	425				Discovery well, Appleby field
11	Travis Peak	6,203		112,000 79,000		1,100	1,300	Extension well, Carthage field
12	Travis Peak	6,576		89,000				Extension well, Carthage field
13	Pettit	7,487	231		1/4	750	340	Discovery well, Henderson field
14	Rodessa	9,852						Dry hole, oil shown in Paluxy
15	Paluxy	6,537						Dry hole
16	Travis Peak	9,000						Dry hole
17	Paluxy	7,506						Dry hole, show heavy oil in Woodbine
18	Paluxy	6,361	247		1/4	170	175	Discovery well, Manziel field

TABLE 3.—*Production Statistics, East Texas Field*[a]

Date, Year 1943	Average Reservoir Pressure at −3300 Ft., Lb. per Sq. In.	Production, Bbl. (42 U. S. Gal.)	Number of Days Shut Down	Date, Year 1943	Average Reservoir Pressure at −3300 Ft., Lb. per Sq. In.	Production, Bbl. (42 U. S. Gal.)	Number of Days Shut Down
Jan. 1	1,015.71	10,065,031	11	Aug. 1	1,012.22	11,413,879	8
Feb. 1	1,020.55	9,058,929	10	Sept. 1	1,008.46	11,383,315	7
Mar. 1	1,016.14	10,053,547	11	Oct. 1	1,010.60	11,398,791	8
Apr. 1	1,020.44	10,517,369	9	Nov. 1	1,007.62	11,365,042	7
May 1	1,019.16	10,509,317	10	Dec. 1	1,007.41	11,344,404	8
June 1	1,016.21	10,031,392	10				
July 1	1,016.98	11,427,879	8	Average and total	1,014.29	128,568,647	107

[a] Data from Texas Railroad Commission.

TABLE 4.—*Oil Recovery Data on Older Woodbine Fields as of January* 1, 1944

Field	County	Cumulative Production, Bbl.	Proved Acres	Net Thickness, Ft.	Acre-feet	Cumulative Production, Bbl. per Acre-foot
Boggy Creek	Anderson, Cherokee	5,172,643	960	34	32,640	158
Cayuga	Anderson, Freestone Henderson	29,118,028	9,700	24	232,800	125
Currie	Navarro	6,976,343	475	20	9,500	734
East Texas	Cherokee, Gregg, Rusk, Smith, Upshur	1,960,512,093	136,000	35	4,760,000	412
Flag Lake	Henderson	576,372	405	5	2,025	285
Mexia	Limestone	98,904,197	3,920	50	196,000	505
Powell	Navarro	112,248,647	2,600	40	104,000	1,079
Richland	Navarro	6,680,197	440	20	8,800	759
Van (Deep)	Van Zandt	139,112,864	4,520	129	583,080	239
Wortham	Freestone	23,071,114	715	35	25,025	922
Cedar Creek[a]	Limestone	330,600	30	10	300	1,102
Nigger Creek[a]	Limestone	2,999,466	170	15	2,550	1,176
Rusk[a]	Cherokee	261,134	200	10	2,000	131

[a] Abandoned fields.

TABLE 5.—*Pipe-line Work in East and East Central Texas during* 1943

Company	Origin	Terminal	Length, Miles	Size, In.	Remarks
		CONSTRUCTION			
Atlantic P. L. Co.	Kinsloe Station	War Emergency P. L. Inc.	1	8	Connected to W.E.P.L. 16-in. heating oil line
Beacon Oil & Ref. Co.	Henderson	East Texas Field	¾	4	Completed to refinery
Central P. L.	Hawkins	Big Sandy	6	4-5-6	To tank-car loading rack
Central P. L.	Quitman	Hawkins	24	4 6	Connects with Central's 4-in. line at Hawkins
Iowa-Payne Oil Co.	Weiland	Dixon	3	3	To loading rack
Lone Star Gas Co.	Cayuga	Dallas	24½ 10½	16 12	Loop between Cayuga field and Dallas Completed
Talco P. L.	Coke	Mt. Pleasant	24 5	6 7	
Texas P. L. Co.	Pleasant Grove	Henderson Station	2½	4	Completed gathering line
War Emeregency P. L.	Longview	East Texas Field	5	16	Field gathering line
War Emergency P. L.	Weho Junction	Longview	6	12	Completed crude line
		REMOVAL			
Atlas P. L. Co.	Longview	Greenwood Road, Louisiana	44	8	Purchased by Humble Oil & Ref. Co.

Oil and Gas Production in the Upper Texas Gulf Coast during 1943

By P. B. Leavenworth,* Member A.I.M.E. and W. H. Hough*

Development in the Upper Texas Gulf Coast during 1943 resulted in the discovery of 11 new fields as compared with 12 discovered in the same area during 1942.

Of the 11 new fields, eight are classed as oil and/or condensate and three as gas fields.

In addition to the new discoveries, several more or less important new horizons and extensions were encountered in some of the older fields, as noted in the text under the heading "New Pays and Extensions."

Drilling

During the year, 418 wells were drilled, as compared with 356 drilled during 1942. Of these, 323 were field wells, of which 188 produced oil, 21 were gas wells and 114 were dry holes. The remaining 95 were wildcats, 12 of which produced oil, 4 produced gas and 79 dry holes.

Distribution of the wildcats with respect to the various trends may be summarized as follows:

Period	Tests	Discoveries
Miocene	4	0
Frio	49	4
Yegua	19	4
Wilcox	23	2

Production

Production in the Upper Texas Gulf Coast during 1943 amounted to 136,852,246 bbl. which is a substantial increase over the 91,340,492 bbl. produced in the same area during 1942.

The production statistics in the text and the accompanying tables include condensate or distillate as oil production, because many Gulf Coast fields produce oils with a wide variation of specific gravities, all of which are commingled in pipe lines.

Table 3 shows by counties all of the drilling and production data applicable to this particular area.

Outstanding Fields of 1943

The Upper Texas Gulf Coast covered in this report has 178 more or less active oil and gas fields, including the 1943 discoveries. Of these Table 4 lists those that were most important from the standpoint of production. Each of these fields produced in excess of one million barrels of oil during 1943. Some of the interesting facts to be noted from this list of some 26 oil fields are: (1) four of the fields—namely, Conroe, Hastings, Friendswood and Thompson—each produced more than 10 million barrels during 1943, whereas Conroe and Hastings were the only fields that produced 10 million barrels during 1942; (2) some of the older fields (discovered prior to 1920), such as Barbers Hill, West Columbia, and Hull, are still producing in excess of one million barrels annually; (3) some of the fields more than doubled their 1942 production—e.g., Anahuac and Friendswood. The large increase in production in practically all instances is the result of increased allowables from wells drilled prior to 1943 and

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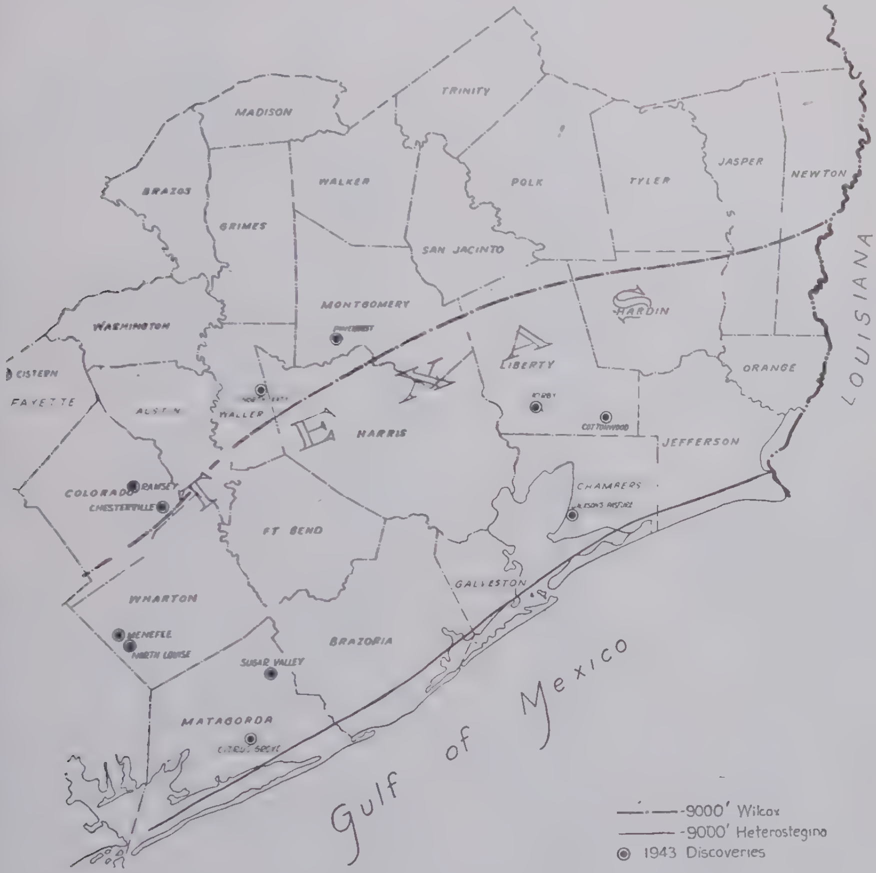
* Gulf Oil Corporation, Houston, Texas.

does not in any way reflect a substantial increase in reserves; (4) 20 of the 26 fields produce from the Frio, which is still the dominant producing horizon in the Upper Texas Gulf Coast.



UPPER TEXAS GULF COAST, SHOWING DISCOVERIES OF 1943.

DISCOVERIES IN 1943

Chesterville, Colorado County.—Magnolia Petroleum Co. completed its No. 1 A. H. & B. D. Anderson on Sept. 1, 1943, from two horizons: at 6850 to 6860 ft. in a Yegua sand, initial production 44 bbl. of 55.3° gravity oil through a ¼-in. choke, gas-oil ratio 131,000:1, and at 9500 to 9540 ft. in a Wilcox sand for an initial production of 88 bbl. of 51° gravity oil through ¼ and ⅜-in. choke series. The well is shut in because a pipe-line outlet is not available. No other wells were drilled during 1943.

The importance of the discovery is difficult to assess at this time. Indications are that it will be a multiple-sand gas-condensate field.

Cistern, Fayette County.—Gas was discovered in the Cistern area in 1942 when Continental Oil Co. completed its No. 1 F. Gobitzch in a Wilcox sand for 1¼ million cubic feet gas daily. The same company's No. 1 Tom E. Cockrill, approximately

TABLE 1.—*Oil and Gas Production in Upper Texas Gulf Coast* 1943

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Number of Oil and/or Gas Wells[f]			Wells Producing[g] Dec. 1943		
				To End of 1943	During 1943	Completed to End of 1943	1943		Oil		Gas
							Completed	Abandoned	Flowing	Artificial Lift	
1	Abel Borden, *Wharton*	1940	40	48,304	2,397	1	0	0	x	x	0
2	Ace, Shallow (Schwab), *Polk*	1934	210	150,728	x	5	0	x	x	x	0
3	Ace, Wilcox (Schwab), *Polk*	1939	250	396,699	68,419	5	0	0	4	1	0
4	Aldine, *Harris*	1939	100	109,632	31,721	3	1	x	2	0	0
5	Alief, *Harris*	1942	100	2,051	1,967	2	1	x	1	0	0
6	Allen, *Brazoria*	1927	10	90,832	0	2	0	0	0	0	0
7	Alta Loma, *Galveston*	1940	240	695,507	176,606	6	0	0	6	0	0
8	Amelia, *Jefferson*	1936	1,000	8,760,892	1,670,652	115	0	x	104	0	0
9	Anahuac, *Chambers*	1935	7,000	32,570,320	8,901,732	389	1	x	349	4	x
10	Angleton, *Brazoria*	1939	700	638,192	1,257	8	0	x	1	0	x
11	Armour, *Matagorda*	1938	125	174,426	10,254	3	0	x	1	1	0
12	Arriola, *Hardin*	1932	100	2,432,227	113,980	21	0	x	0	12	0
13	Bailey's Prairie, *Brazoria*	1940	40	1,766	x	2	0	x	x	x	x
14	Bammel, *Harris*	1937	2,200	958,738	40,000	20	0	x	1	x	x
15	Barber's Hill, *Chambers*	1916	500	79,321,872	2,343,308	426	0	x	21	104	0
16	Batson, Shallow, *Hardin*	1903	500	38,371,076	131,393	1,019	0	x	0	151	0
17	Batson, Deep, *Hardin*	1934	150	2,368,012	93,636				1	7	0
18	Bay City (Van Vleck), *Matagorda*	1934	1,240	6,485,223	1,221,148	59	0	x	52	1	0
19	Big Creek, *Ft. Bend*	1922	240	10,326,736	180,133	91	0	x	0	15	0
20	Big Hill, *Jefferson*	1923	50	14,098	0	6	0	x	0	0	0
21	Blessing, *Matagorda*	1940	2,000	25,358	x	7	0		x	x	x
22	Blue Ridge, *Ft. Bend*	1919	400	12,195,529	193,027	218	0	x	6	41	0
23	Boling, *Wharton-Ft. Bend*	1925	400	8,270,881	384,344	249	7	x	12	36	0
24	Bryan Heights, *Brazoria*		10	x	x	1	0	0	0	0	0
25	Brenham, *Washington*	1915	50	388,425	2,401	37	0	x	0	6	0
26	Brookshire, *Waller-Austin*	1934		22,420	538	1	0	x	0	0	0
27	Buckeye, *Matagorda*	1932	200	874,347	44,505	5	1	x	2	1	0
28	Buck Snag, *Colorado*	1942	40	13,588	13,443	1	0	0	1	0	0
29	Buttermilk Slough, *Matagorda*	1939	50	10,774	x	1	0	0	0	0	0
30	Call, *Newton*	1937	100	11,500	0	1	0	0	0	0	0
31	Camp Eleven, *Tyler*	1942	80	166,290	90,242	2	0	x	2	0	0
32	Caplen, *Galveston*	1939	510	817,754	308,912	21	1	x	14	0	x
33	Cedar Bayou, *Chambers*	1938	40	23,035	1,802	1	0	x	0	1	0
34	Cedar Point, *Chambers*	1938	560	1,910,384	649,129	19	2	x	17	0	x
35	Cheek, *Jefferson*	1937	60	72,810	x	3	0	x	x	x	x
36	Chenango, *Brazoria*	1941	120	75,366	17,506	3	0	x	1	0	0
37	Chesterville, *Colorado*	1943	100	Shut in		1	1	0	Shut in		
38	Chocolate Bayou, *Brazoria*	1939	500	414,344	77,848	4	0	x	2	0	0
39	Cistern, *Fayette*	1943	40	2,019	2,019	2	1	0	1	0	5/1
40	Citrus Grove, *Matagorda*	1943	40	0	0	1	1	0	0	0	1
41	Clam Lake, *Jefferson*	1937	550	617,855	201,642	16	1	x	10	4	x
42	Clay Creek, *Washington*	1928	340	4,768,517	22,245	70	1	x	3	45	x
43	Clear Lake, *Harris*	1938	2,100	3,252,194	1,443,127	62	0		37	1	x
44	Cleveland, *Liberty*	1933	700	1,532,263	79,010	21	0	x	1	7	x
45	Clinton, *Harris*	1936	150	357,731	39,953	16	0	x	5	2	x
46	Clodine, *Ft. Bend*	1941	850	501,483	282,047	21	10	0	21	0	x
47	Collegeport, *Matagorda*	1939	3,900	0	0	7	0	x	0	0	
48	Conroe, *Montgomery*	1931	17,660	161,943,397	19,957,155	991	0	x	829	88	x
49	Cotton Lake, *Chambers*	1936	175	932,110	86,942	12	0	x	2	6	0
50	Cottonwood, *Liberty*	1943	100	x	x	1	1	0	1	0	0
51	Damon Mound, *Brazoria*	1916	260	9,874,265	70,477	132	1	x	0	27	0
52	Danbury, Shallow, *Brazoria*	1934	400	905,253	171,289	29	8	x	3	11	0
53	Danbury, Deep, *Brazoria*	1942	Incl.	184,560	168,424				5	0	x
54	Dickinson, *Galveston*	1934	2,700	8,557,020	578,956	127	0	x	40	25	x
55	Double Bayou, *Chambers*	1942	200	x	x	3	x	x	x	x	x
56	Dyrsdale, *Harris*	1940	1,200	1,392,147	605,155	52	3	x	39	10	x
57	East Bernard, *Wharton*	1940	40	1,211	x	1	0	x	0	0	0
58	Esperson, *Liberty*	1929	1,600	7,994,531	608,662	118	3	x	24	38	x
59	Esperson, *South*	1939	Incl. above	1,306,361	211,935				23	0	x
60	Eureka, *Harris*	1935	900	3,877,195	491,392	39	0	x	8	15	x
61	Fairbanks, *Harris*	1938	4,000	13,966,562	2,716,712	309	0	x	275	16	x
62	Fannett, *Jefferson*	1927	900	4,875,342	1,240,008	66	0	0	24	12	x
63	Fig Ridge, *Chambers*	1940	1,500	1,128,768	840,272	27	3		24	0	x
64	Fishers Reef, *Chambers*	1940	100	91,235	32,989	2	0		2	0	x
65	Fostoria, *Montgomery*	1942	40	7,501	2,327	1	0		0	1	0
66	Fred, *Tyler*	1941	260	88,309	49,441	3	1		3	0	0

TABLE 1.—(*Continued*)

Line Number	Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Initial	Avg./End 1943		Gravity A.P.I. at 60° F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Net Ft.[n]	Structure[o]	Name	Depth of Hole, Ft.
1	*x*	*x*	0	35	*x*	Frio, Olig	S	Por	4,758	10	*x*	Frio	6,557
2	*x*	*x*	0	40-53	*x*	Cockfield, Eoc	S	Por	4,805	10	D	Wilcox	8,553
3	*x*	*x*	0	34-36	0.10	Wilcox, Eoc	S	Por	7,748	20	D	Wilcox	8,553
4	*x*	*x*	0	37-66	*x*	Yegua, Eoc	S	Por	6,622	10	D	Cook Mountain	7,664
5	*x*	*x*	0	52	*x*	Yegua, Eoc	S	Por	7,910	25	*x*	Cook Mountain	8,637
6	*x*	*x*	0	*x*	*x*	Miocene, Mio	S	Por	4,362	*x*	Ds	Miocene	5,958
7	*x*	*x*	0	34-38	*x*	Frio, Olig	S	Por	9,160	18	D	Frio(Mar), Olig	11,117
8	925	*x*	0	27-29	*x*	Frio, Olig	S	Por	6,778	10	D	Vicksburg, Olig	7,882
9	3,260	*x*	0	34	0.08	Frio, Olig	S	27	7,145	60	D	Frio	8,749
10	*x*	*x*	0	50	*x*	Frio, Olig	S	Por	10,000	6	D	Frio	11,451
11	*x*	*x*	0	33-37	*x*	Frio, Olig	S	Por	6,614	4	D	Frio	7,531
12	*x*	*x*	0	30-34	*x*	Mio & Frio, Mio, Olig	S	Por	3,000	50	Ds	Vicksburg	6,743
13	*x*	*x*	0	46	*x*	Frio	S	Por	10,535	12	*x*	Frio	11,860
14	*x*	*x*	0	58	*x*	Cockfield	S	Por	6,170	10	D	Wilcox	10,574
15	*x*	*x*	0	25-29	*x*	Cap, Mio, Olig	S	Por	800	90	Ds	Jackson	8,150
16	*x*	*x*	0	24-38	*x*	Cap, Mio, Olig	S	Por	245	*x*	Ds	Cook Mountain	6,828
17	*x*	*x*	0			Yegua, Cook Mt., Eoc	S	Por	4,600	30	Ds		
18	*x*	*x*	0	35-36	0.087	Frio, Olig	S	27	7,023	*x*	D	Vicksburg	11,465
19	*x*	*x*	0	20-42	0.12	Pli, Mio, Frio, Pli, Mio, Olig	S	Por	800	21	Ds	Cook Mountain	8,273
20	*x*	*x*	0	20-42	*x*	Mio, Frio, Mio, Olig	S	Por	1,700	10-50	Ds	Frio	10,186
21	*x*	*x*	0	56	*x*	Frio, Olig	S	Por	8,290	15	D	Frio	8,525
22	*x*	*x*	0	21-38	0.08	Mio, Frio, Mio, Olig	S	Por	1,956	55	Ds	Yegua	5,280
23	*x*	*x*	0	19-33	*x*	Mio, Frio, Mio, Olig	S	Por	377	15-60	Ds	Vicksburg	6,281
24	*x*	*x*	0	39	*x*	Mio	S	Por	3,400	20	Ds	Oligocene	7,600
25	*x*	*x*	0	14-19	*x*	Mio, Mio	S	Por	183	*x*	Ds	Wilcox	5,039
26	100	*x*	0	23	*x*	Frio, Olig	S	Por	2,966	16	*x*	Yegua	7,200
27	1,045	*x*	0	37-39	*x*	Frio, Olig	S	Por	7,761	60	D	Frio	10,503
28	*x*	*x*	0	50	*x*	Yegua, Eoc	S	Por	6,143	*x*	*x*	Yegua	6,997
29	1,140	*x*	0	45	*x*	Frio, Olig	S	20	7,850	10	A	Frio	9,582
30	1,475	*x*	0	39	*x*	Cockfield, Eoc	S	Por	6,908	10	D	Yegua	7,700
31	*x*	*x*	0	45-46	0.05	Wilcox, Eoc	S	Por	7,797	10	*x*	Wilcox	8,007
32	3,300	*x*	0	30-50	0.04	Mio, Olig	S	Por	5,975	10-40	D	Oligocene	8,009
33	*x*	*x*	0	*x*	*x*	Frio	S	Por	*x*	*x*	*x*	Frio	*x*
34	2,750	*x*	0	28-38	*x*	Mio, Frio, Mio, Olig	S	Por	5,943	62	D	Oligocene	8,507
35	*x*	*x*	0	44-60	*x*	Frio, Olig	S	Por	8,326	15	F	Oligocene	9,007
36	*x*	*x*	0	31	*x*	Frio, Olig	S	Por	8,564	10	D	Frio	10,497
37	*x*	*x*			*x*	Yegua, Wilcox, Eoc	S	Por	6,850	10-40	*x*	Wilcox	12,911
38	*x*	*x*	0	38-57	*x*	Frio, Olig	S	Por	9,660	16-50	D	Frio	12,505
39	1,000	*x*	0		*x*	Reklaw, Eoc	S	Por	1,187	5	*x*	Wilcox	4,489
40	*x*	*x*	0	Gas	*x*	Miocene, Mio	S	Por	3,980	15	A	Oligocene	11,612
41	*x*	*x*	0	22-44	*x*	Miocene, Mio	S	Por	2,387	15	Ds	Frio	8,198
42	*x*	*x*	0	22-27	*x*	Mio, Cockfield, Wilcox, Mio, Eoc	S	Por	1,124	120	Ds	Wilcox	8,306
43	650	*x*	0	26-31	*x*	Frio, Olig	S	25	5,790	40	D	Frio	7,210
44	2,400	*x*	0	40	*x*	Cockfield, Wilcox, Eoc	S	15	5,672	8	D	Wilcox	10,075
45	*x*-4,800	*x*	0	22-48	*x*	Mio, Cockfield, Mio, Eoc	S	Por	3,207	20	D	Yegua	8,763
46	*x*	*x*	0	41-51	*x*	Yegua, Eoc	S	Por	7,463	10	D	Cook Mountain	8,300
47	*x*	*x*	0	Gas	*x*	Miocene	S	Por	3,750	15	A	Miocene	5,813
48	2,275	*x*	0	35-40	0.04	Cockfield, Eoc	S	27	5,000	30	D	Wilcox	9,040
49	*x*	*x*	0	29	*x*	Frio, Olig	S	Por	6,277	10	D	Vicksburg	8,580
50	*x*	*x*	0		*x*	Frio, Olig	S	Por	7,704	6	*x*	Vicksburg	8,205
51	*x*	*x*	0	21-33	*x*	Mio, Frio, Mio, Olig	S	Por	1,406	40	Ds	Vicksburg	7,903
52	*x*	*x*	0	22-28	*x*	Mio, Mio	S	Por	1,600	12	Ds	Frio	9,711
53						Frio, Olig	S	Por	4,465	20	Ds		
54	1,250	*x*	0	37	*x*	Frio, Olig	S	Por	7,800	20	D	Frio	9,463
55	*x*	*x*	0	*x*	*x*	Frio, Olig	S	Por	7,525	*x*	D	Frio	9,200
56	*x*	*x*	0	22	0.04	Frio, Olig	S	Por	4,050	10	D	Yegua	8,515
57	*x*	*x*	0	55	*x*	Cook Mountain, Eoc	S	Por	8,070	10	*x*	Cook Mountain	8,461
58	*x*	*x*	0	21-41	0.02	Miocene, Olig	S	Por	2,275	*x*	Ds	Cook Mountain	9,734
59					0.04	Yegua-Cook Mt., Eoc	S	Por	7,341	20	Ds		
60	*x*	*x*	0	37-51	*x*	Yegua, Eoc	S	Por	7,662	25	D	Cook Mountain	9,038
61	3,000	*x*	0	38-8	*x*	Yegua, Eoc	S	Por	6,505	20	AF	Cook Mountain	7,940
62	540	*x*	0	26-38	*x*	Mio, Frio, Mio, Olig	S	Por	3,250	20-250	Ds	Vicksburg	10,595
63	*x*	*x*	0	32	0.07	Frio, Olig	S	Por	8,214	60	D	Frio	9,021
64	*x*	*x*	0	32	*x*	Frio, Olig	S	Por	8,962	5	D	Frio	9,952
65	*x*	*x*	0	39	*x*	Cockfield, Eoc	S	Por	5,790	4	*x*	Wilcox	11,794
66	*x*	*x*	0	39	*x*	Wilcox, Eoc	S	Por	8,180	15	D	Wilcox	8,500

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c] To End of 1943	Oil Production Total, Bbl.[c] During 1943	Number of Oil and/or Gas Wells[f] Completed to End of 1943	Number of Oil and/or Gas Wells[f] 1943 Completed	Number of Oil and/or Gas Wells[f] 1943 Abandoned	Wells Producing[g] Dec. 1943 Oil Flowing	Wells Producing[g] Dec. 1943 Oil Artificial Lift	Wells Producing[g] Dec. 1943 Gas
67	Friendswood (Webster), *Harris*	1937	4,000	24,070,747	11,456,732	215	3		212	2	*x*
68	Garwood	1932	275	6,198	0	5	0	0	0	0	0
69	Gillock, *Galveston*	1935	2,250	9,591,350	1,222,500	98	0	*x*	69	19	*x*
70	Goodrich, *Polk*	1941	120	57,449	21,332	3	0	0	0	3	0
71	Goose Creek, *Harris*	1907	1,200	79,240,724	381,281	914	0	*x*	0	83	0
72	Greens Lake, *Galveston*	1936	225	125,491	21,778	11	0		1	0	*x*
73	Gulf (Big Hill), *Matagorda*	1904	35	211,000	0	8	0	0	0	0	0
74	Halls Bayou, *Brazoria*	1942	100	*x*	*x*	2	1	0	1	0	0
75	Hamman, *Matagorda*	1936	1,100	4,307,432	516,058	30	0	*x*	4	16	*x*
76	Hampton, *Hardin*	1942	40	26,661	14,911	2	0	*x*	1	0	0
77	Hankamer, *Liberty*	1929	400	6,674,356	259,938	50	0	*x*	8	24	0
78	Hardin, *Liberty*	1935	2,750	9,938,671	1,332,209	175	0	*x*	69	68	*x*
79	Hastings, *Brazoria*	1934	5,800	63,544,941	18,003,529	693	0		667	22	*x*
80	Hawkinsville, *Matagorda*	1936	0	2,000	0	1	0	0	0	0	0
81	High Island, *Galveston*	1922	320	19,676,096	800,547	139	0	*x*	16	40	0
82	Hillje, *Wharton*	1939	750	668,082	168,353	18	0	*x*	8	7	*x*
83	Hitchcock, *Galveston*	1937	250	1,207,104	181,369	15	1	*x*	9	4	*x*
84	Hockley, *Harris*	1923	10	23,511	0	4	0	0	0	0	0
85	Hoskins Mound, *Brazoria*	1906	90	104,739*x*	0	9	0	0	0	0	0
86	Hull, *Liberty*	1918	875	97,952,134	1,886,343	823	1	*x*	10	161	0
87	Humble, *Harris*	1904	2,350	128,362,904	797,334	1,817	2	*x*	9	221	0
88	Jackson Pasture, *Chambers*	1943	200	*x*	*x*	2	2	0	2	0	0
89	Joes' Lake, *Tyler*	1937	2,350	3,829,230	543,895	46	0	*x*	32	9	*x*
90	Joyce Richardson, *Harris*, 6500-ft	1940	150	62,667	13,860	7	0	0	1	0	*x*
91	6900-ft	1940	above	65,363	30,040				1	0	
92	Katy, *Waller-Harris*	1938	13,000	299,350	85,542	*x*	11	*x*	*x*	0	*x*
93	Katy, North, *Waller*	1943	500	58,152	58,152	7	7	0	7	0	*x*
94	Kirby, *Liberty*	1943	200	60,843	60,843	4	4	0	4	0	*x*
95	Kubela, *Wharton*	1935	650	1,526,384	190,793	21	0	*x*	6	12	*x*
96	La Belle, *Jefferson*	1937	900	797,523	154,042	8	0	*x*	4	1	*x*
97	Lakeview, *Wharton*	1941	60	*x*	*x*	3	0	*x*	*x*	*x*	*x*
98	Lake Creek, *Montgomery*	1941	1,000	190,835	146,974	13*x*	0	*x*	13*x*	*x*	*x*
99	League City, *Galveston*	1938	740	3,081,283	776,383	37	0	*x*	31	3	*x*
100	Lissie, *Wharton*	1940	500	1,014	*x*	1	0	*x*	*x*	*x*	*x*
101	Livingston, Cockfield, *Polk*	1930	1,800	7,764,961	506,758	99	0		4	66	0
102	Sparta, *Polk*	1942	Inc. above	35,599	26,933				1	0	0
103	Wilcox, *Polk*	1942	Inc. above	27,838	14,943				0	1	0
104	Lochridge, *Brazoria*	1937	1,900	4,545,952	659,997	49	2	*x*	29	10	*x*
105	Lost Lake, *Chamberg*	1929	110	1,044,182	683	13	0	*x*	0	1	0
106	Louise, *Wharton*	1933	1,600	4,260,516	406,312	52	0	*x*	5	31	*x*
107	Lovell's Lake, *Jefferson*	1938	3,000	6,337,483	2,050,693	104*x*	11	*x*	99	0	0
108	Lucky, *Matagorda*	1941	540	123,134	68,509	4	2	*x*	3	*x*	*x*
109	Magnet-Withers, *Wharton*	1936	9,000	15,448,337	3,254,909	275	0	*x*	216	45	*x*
110	Magnolia, *Montgomery*	1941	*x*	1,682	*x*	1	0	*x*	*x*	*x*	0
111	Manvel, *Brazoria*	1931	1,800	25,909,132	2,665,524	195	0	*x*	94	69	*x*
112	Markham, *Matagorda*	1908	260	8,944,627	259,204	160*x*	1	*x*	11	29	*x*
113	Martha, *Liberty*	1939	500	653,034	196,371	12	0	0	5	7	0
114	McFaddin, *Jefferson*		0	0	0	0	0	0	0	0	0
115	Menefee, *Wharton*	1943		0	0	1	1	0	0	0	1
116	Mercy, *San Jacinto*	1942		1,069,896	898,385	37	23	0	37	0	*x*
117	Millican, *Brazos*	1942	40	0	0	1	0	*x*	0	0	*x*
118	Moore's Field (Orchard), *Ft. Bend*	1926	300	4,084,600	38,428	35	0	*x*	3	6	*x*
119	Moss Bluff, *Liberty*	1930	10	179,000	0	5	0	0	0	0	0
120	Mykawa, *Harris*	1929	350	4,765,639	139,228	45	0		0	29	0
121	Nash, *Ft. Bend*	1926	260	1,664,811	0	26	0	0	0	0	0
122	Needville, *Ft. Bend*	1942	60	63,763	24,657	5	0	*x*	3	0	*x*
123	Nome, *Jefferson*	1936	750	3,521,635	640,365	44	0	*x*	17	21	*x*
124	North Bay City, *Matagorda*	1942	250	166,450	145,569	7	3	0	5	1	0
125	North Dayton, *Liberty*	1905	100*x*	2,374,171	1,200	64	0	*x*	*x*	*x*	0
126	North Houston, *Harris*	1938	1,000	341,013	43,659	7	1	*x*	4	0	*x*

TABLE 1.—(*Continued*)

Line Number	Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[f]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Net Ft.,[n]	Structure[o]	Name	Depth of Hole, Ft.
67	950	*x*	0	30	0.07	Frio, Olig	S	30	5,488	150	D	Vicksburg	8,450
68	*x*	*x*	0	44	*x*	Frio, Yegua, Olig, Eoc	S	12 S	4,021	15–30	D	Wilcox	10,536
69	1,250	*x*	0	37	*x*	Frio, Olig	S	Por	8,300	12	D	Frio	9,463
70	*x*	*x*	0	32	*x*	Cockfield, Eoc	S	Por	4,030	4	D	Wilcox	9,966
71	*x*	*x*	0	20–36	0.08	Pli, Mio, Olig	S	Por	1,000	4	D	Jackson(?)	6,967
72	1,300	*x*	0	22–52	*x*	Pli, Mio	S	20–25	2,712	10	Ds	Oligocene	9,636
73	*x*	*x*	0	*x* *x*	*x*	Cap-Mio	S-Cav	Por	862	*x*	Ds	*x*	4,586
74	8,500	8,500	0	47	*x*	Frio, Olig	S	Por	9,737	22	D	Frio	11,670
75	800	*x*	0	37	*x*	Frio-Olig	S	Por	8,182	10	D	Frio	
76	*x*	*x*	0	40	0.07	Cockfield-Eoc	S	Por	6,952	2	*x*	Cockfield	7,018
77	424	*x*	0	18–32	*x*	Mio, Frio-Mio, Olig	S	20	2,407	29	Ds	Vicksburg	7,891
78	900	*x*	0	37–56	0.07	Yegua-Eoc	S	30	7,547	10	D	Yegua	8,110
79	2,740	*x*	0	30–33	*x*	Frio-Olig	S	30	5,157	200	D	Vicksburg	8,793
80	200	*x*	0	*x*	*x*	Mio	S	Por	5,150	10	Ds	Oligocene	6,905
81	*x*	*x*	0	31	*x*	Mio	S	Por	1,500	40	Ds	Oligocene	7,179
82	*x*	*x*	0	25	*x*	Frio	S	Por	5,220	10	D	Frio	7,004
83	800	*x*	0	29–31	*x*	Mio	S	Por	5,134	12	D	Frio	10,460
84	*x*	*x*	0	22	*x*	Cap rock, Olig	S-L	Por	1,800	30	Ds	Yegua	7,510
85	*x*	*x*	0	21	*x*	Mio	S	Por	600	23	Ds	Miocene	4,126
86	*x*	*x*	0	17–39	0.06	Cap, Mio, Olig, Yegua Cook Mt.—Cap, Mio, Olig, Eoc	S	Por	400	63	Ds	Cook Mountain	9,669
87	*x*	*x*	0	17–45	*x*	Cap, Mio, Olig, Yegua-Cap, Mio, Olig, Eoc	S	Por	700	4–200	Ds	Cook Mountain	8,181
88	*x*	*x*	0		*x*	Frio-Olig	S	Por	8,082	6	*x*	Frio	9,515
89	1,425	*x*	0	40–47	*x*	Wilcox-Eoc	S	Por	7,600	30	D	Wilcox	9,014
90	*x*	*x*	0	42–58	*x*	Cockfield-Eoc	S	Por	6,654	7	D	Cockfield	7,250
91													
92	*x*	*x*	0	*x*	*x*	Yegua-Eoc	S	27	6,400	100	D	Wilcox	11,078
93	*x*	*x*	0	*x*	*x*	Yegua-Eoc	S	Por	6,620	10	D	Wilcox	11,078
94	*x*	*x*	0	*x*	*x*	Yegua-Eoc	S	Por	8,400	30	D	Cook Mountain	9,518
95	*x*	*x*	0	*x*	*x*	Frio-Olig	S	Por	4,596	*x*	D	Frio	6,260
96	7,000	*x*	0	37	0.06	Marginulina-Olig	S	30	8,260	11	D	Frio	10,147
97	*x*	*x*	0	24	*x*	Mio	S	Por	3,185	15	*x*	Cockfield	7,607
98	*x*	*x*	0	61	0.04	Wilcox-Eoc	S	Por	9,200	50	D	Wilcox	13,330
99	1,100 2,100	*x* *x*	0	40	*x*	Frio-Olig	S	30	8,695	20	D	Vicksburg?	11,402
100	*x*	*x*	0	58	*x*	Yegua-Eoc	S	Por	6,728	6	*x*	Wilcox	10,116
101	700	*x*	0	40	0.05	Cockfield-Eoc	S	Por	3,285	20	D	Midway?	11,023
102	*x*	*x*	0	*x*		Cook Mountain-Eoc	S	Por	6,300	*x*			
103	*x*	*x*	0	*x*		Wilcox-Eoc	S	Por	7,036	16			
104	2,100	*x*	0	26	0.01	Frio-Olig	S	20	6,309	20	D	Vicksburg	9,684
105	*x*	*x*	0	22	*x*	Frio-Olig	S	Por	2,679	33	Ds	Frio	7,471
106	1,300–1,850	*x*	0	26–38	*x*	Frio-Olig	S	Por	5,135	15	D	Vicksburg	8,271
107	1,850	*x*	0	26	0.05	Frio-Olig	S	30	7,113	22	D	Frio	8,189
108	*x*	*x*	0	39	*x*	Frio, Olig	S	Por	8,883	10	D	Frio	10,500
109	2,350	*x*	0	26	*x*	Frio, Olig	S	Por	5,490	20	AF	Vicksburg	9,200
110	*x*	*x*	0	57	*x*	Wilcox, Eoc	S	Por	8,448	10	D	Wilcox	10,008
111	*x*	*x*	0	26	*x*	Mio, Frio, Mio, Olig	S	22–28	3,990	25	D	Vicksburg	7,957
112	*x*	*x*	0	25–40	*x*	Cap, Mio	S, L	Por Cav	936	20	Ds	Vicksburg	8,418
113	3,509	*x*	0	41	*x*	Yegua, Eoc	S	30	8,100	5	D	Yegua	9,109
114	0	0	0		0	Miocene	*x*	*x*	*x*	*x*	Ds	Miocene	6,576
115	*x*	*x*	0	*x*	*x*	Frio, Olig	S	Por	4,540	10	D	Frio	4,600
116	*x*	*x*	0	38	0.04	Wilcox, Eoc	S	17	8,250	20	D	Wilcox	11,807
117	*x*	*x*	0	Gas	*x*	Wilcox, Eoc	S	Por	3,342	6	Ds	Wilcox	5,511
118	375	*x*	0	22–51	*x*	Mio, Frio, Yegua, Mio, Olig, Eoc	S	20	1,265	25	Ds	Cook Mountain	10,104
119	*x*	*x*	0	*x*	*x*	Cap, Olig	S, L	Por Cav	800	33	Ds	Vicksburg	7,375
120	*x*	*x*	0	27	*x*	Mio, Frio, Mio, Olig	S	Por	4,100	30	D	Yegua	7,178
121	*x*	*x*	0	23	*x*	Mio, Frio, Mio, Olig	S	Por	3,700	60	Ds	Vicksburg	7,965
122	*x*	*x*	0	*x*	*x*	Frio, Olig	S	Por	5,176	5	D	Yegua	11,132
123	2,550	*x*	0	27	0.25	Marginulina, Olig	S	Por	4,775	12	D	Vicksburg	9,045
124	*x*	*x*	0	35	*x*	Frio, Olig	S	Por	7,864	10	D	Frio	8,852
125	*x*	*x*	0	22–33	*x*	Cap, Mio	S, L	Cav Por	400	*x*	Ds	Oligocene	5,700
126	*x*	*x*	0	*x*	*x*	Yegua, Eoc	S	Por	6,795	10	D	Yegua	7,664

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Number of Oil and/or Gas Wells[f]			Wells Producing[g] Dec. 1943		
							1943		Oil		
				To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned	Flowing	Artificial Lift	Gas
127	North Louise, *Wharton*	1943	100	0	0	1	1	0	0	0	1
128	North Markham, *Matagorda*	1938	1,350	984,073	522,042	31	12	0	31	0	0
129	North Withers, *Wharton*	1942	5,000	4,577,002	2,731,709	121	0	*x*	118	3	*x*
130	Old Ocean, *Brazoria*	1934	10,580	23,397,627	4,830,749	118	7	0	117	1	*x*
131	Orange (Cow Bayou), *Orange*	1913	400	33,191,699	108,039	328	0	*x*	0	35	0
132	Oyster Bayou, *Chambers*	1941	1,400	1,389,142	1,213,856	19	6	0	19	0	*x*
133	Palacios, *Matagorda*	1937	300	151,044	2,535	5	0	*x*	1	0	0
134	Pickett Ridge, *Wharton*	1935	1,200	3,878,551	530,548	51	0	*x*	16	30	0
135	Pierce Junction, *Harris*	1921	350	36,127,413	491,207	201	1	*x*	11	53	0
136	Pinehurst, *Montgomery*	1943	100	32,904	32,904	1	1	0	1	0	0
137	Pledger, *Brazoria*	1932	*x*	17,000	*x*	13	0	*x*	*x*	*x*	*x*
138	Port Neches, *Orange*	1929	300	5,672,674	146,736	21	1	*x*	1	13	0
139	Raccoon Bend, *Austin-Walker*	1927	1,624	28,076,887	2,674,351	250	0	*x*	57	100	0
140	Ramers Island, *Tyler*	1942	40*x*	*x*	*x*	1	0	*x*	*x*	*x*	*x*
141	Ramsey, *Colorado*	1943	100	Shut in		1	1	0	Shut in	0	0
142	Red Fish Reef, *Chambers*	1940	1,020	1,289,382	600,575	20	0	0	15	0	*x*
143	Rockland, *Jasper*	1928	20	43,704	*x*	10	0	*x*	*x*	*x*	0
144	Rosenberg, *Ft. Bend*	1939	200	22,307	*x*	2	0	*x*	*x*	*x*	0
145	Rosslyn, *Harris*	1938	100	48,346	476	1	0	0	1	0	0
146	Rowan, *Brazoria*	1940	460	574,769	164,276	7	0	0	7	0	0
147	Sabine Pass, *Jefferson*	1941	50	10,218	*x*	2	0	*x*	*x*	*x*	*x*
148	Sandy Point, *Brazoria*	1937	80	346,200	33,544	11	0	*x*	0	3	0
149	Saratoga, *Hardin*	1901	500	30,215,270	233,440	779	1	*x*	0	214	0
150	Satsuma, *Harris*	1936	580	820,960	143,911	18	1	*x*	6	4	0
151	Seabreeze, *Chambers*	1936	650	1,088,336	390,462	15	0	*x*	11	0	*x*
152	Sealy, *Austin*	1942	40	*x*	*x*	1	0	*x*	*x*	*x*	*x*
153	Segno (Deep), *Polk*	1938	2,100	5,066,116	1,266,607	81	0	*x*	63	8	0
154	Segno (Shallow), *Polk*	1936	425	3,086,520	334,442	37	0	0	24	13	0
155	Shepherd, *San Jacinto*	1940	40	24,442	*x*	1	0	*x*	*x*	*x*	*x*
156	Sheppards Mott, *Matagorda*	1936	*x*	1,000	0	2	1	*x*	*x*	*x*	*x*
157	Sheridan, *Colorado*	1940	1,550	250,385	85,388	7	0	*x*	3	0	0
158	Silsbee, *Hardin*	1936	1,000	3,978,850	668,649	51	0	*x*	21	19	0
159	Sour Lake, *Hardin*	1902	960	80,844,649	357,795	815	6	*x*	10	136	0
160	South China, *Jefferson*	1931	250	679,759	261,555	16	0	*x*	11	4	0
161	South Cotton Lake, *Chambers*	1937	1,000	3,224,803	444,202	54	0	*x*	14	20	0
162	South Houston, *Harris*	1935	620	9,032,763	1,603,138	91	0	*x*	66	23	0
163	South Liberty, *Liberty*	1925	250	16,174,289	120,921	317	0	*x*	3	33	0
164	Spanish Camp	1936	2,000	0	0	12	0	*x*	0	0	*x*
165	Spindletop, *Jefferson*	1901	500	127,392,981	373,273	1,385	0	*x*	5	118	0
166	Splendora, *Montgomery*	1934	100	1,000	0	1	0	0	0	0	0
167	Spurger, *Tyler*	1940	*x*	52,845	0	1	0	0	0	0	0
168	Stowell, *Jefferson*	1941	1,800	2,145,631	1,876,718	43	21	0	43	0	0
169	Stratton Ridge, *Brazoria*	1922	25	12,000	0	5	0	0	0	0	0
170	Sugarland, *Ft. Bend*	1928	1,200	33,097,906	1,836,215	71	0	*x*	33	18	0
171	Sugar Valley, *Matagorda*	1943	100	Shut in		1	1	0	Shut in		
172	Thompson, *Ft. Bend*, 3600-ft. sand	1931	6,515	2,115,544	562,538	374	0	*x*	21	3	0
173	5000-ft. sand	1931		48,705,706	6,660,401		0	*x*	171	27	0
174	South	1939		5,700,136	2,218,733		0	*x*	79	2	0
175	North	1939		2,291,462	583,809		0	*x*	38	0	0
176	Tomball, *Harris*	1933	8,900	26,151,851	3,239,937	537	0	*x*	278	174	*x*
177	Turtle Bay, *Chambers*	1935	875	3,004,362	510,951	39	0	*x*	27	11	*x*
178	Turtle Bay (East), *Chambers*	1943	200	21,580	21,580	2	2	0	2	0	0
179	West Aldine, *Harris*	1942	40	3,872	2,736	1	0	*x*	*x*	*x*	0
180	West Beaumont, *Jefferson*	1936	650	5,344,815	720,221	60	1	*x*	24	31	1
181	West Columbia, *Brazoria*	1902	720	93,346,996	2,049,867	381	2	*x*	105	39	0
182	West Conroe, *Montgomery*	1941	40	22,833	8,642	1	0	0	1	0	0
183	West Garwood, *Colorado*	1941	200	111,239	29,073	5	0	*x*	3	0	0
184	West Orange, *Orange*	1937	250	3,400,390	432,689	48	0	*x*	12	32	0
185	West Port Neches, *Orange*	1936	400	1,181,236	377,317	28*x*	0	*x*	15	11	0
186	West Silsbee, *Hardin*	1941	250	83,712	35,688	2	0	0	2	0	0
187	Willow Slough, *Chambers*	1938	850	789,552	148,009	8	1	0	7	0	0
188	Wilson Creek, *Matagorda*	1937	80	193,658	*x*	2	0	0	2	0	0

TABLE 1.—(*Continued*)

Line Number	Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
127	*x*	*x*	0	*x*	*x*	Frio, Olig	S	Por	4,088	5	*x*	Vicksburg	6,007
128	3,450	*x*	0	36	*x*	Frio, Olig	S	Por	7,702	20	D	Frio	9,010
129	*x*	*x*	0	26	*x*	Frio, Olig	S	Por	5,490	20	AF	Vicksburg	9,200
130	4,700	*x*	0	52–68	*x*	Frio, Olig	S	27	8,636	200	D	Oligocene	14,378
131	*x*	*x*	0	20–42	*x*	Mio, Frio, Mio, Olig	S	Por	2,500	30	Ds	Frio	7,604
132	*x*	*x*	0	36	*x*	Frio, Olig	S	Por	8,250	20	D	Frio	8,835
133	*x*	*x*	0	54	*x*	Frio, Olig	S	Por	7,830	15	D	Frio	11,337
134	2,053	*x*	0	26	*x*	Frio, Olig	S	33	4,596	15	A	Jackson	8,888
135	*x*	*x*	0	21–41	0.07	Mio, Frio, Vicksburg, Mio, Olig	S	Por	3,142	45	Ds	Jackson	7,165
136	*x*	*x*	0		*x*	Wilcox, Eoc	S	Por	8,760	22	*x*	Wilcox	11,921
137	2,450	*x*	0	56	*x*	Frio, Olig	S	Por	6,580	100	D	Vicksburg	8,061
138	*x*	*x*	0	25	0.06	Mio, Frio, Mio, Olig	S	Por	3,150	40	Ds	Vicksburg	7,667
139	275–1,800	*x*	0	26–33	*x*	Jackson, Cockfield, Eoc	S	Por	3,149	30	D	Wilcox	8,589
140	*x*	*x*	0	45	*x*	Yegua, Eoc	S	Por	5,397	3	*x*	Wilcox	8,454
141	*x*	*x*	0	*x*	*x*	Wilcox, Eoc	S	Por	8,320	20	*x*	Wilcox	10,505
142	*x*	*x*	0	35–57	*x*	Frio, Olig	S	Por	8,796	15	*x*	Frio	11,008
143	*x*	*x*	0	21–35	*x*	Jackson, Yegua, Eoc	S	Por	1,275	6	F	Wilcox	8,001
144	*x*	*x*	0	55	*x*	Cockfield, Eoc	S	Por	7,713	10	D	Cook Mountain	8,530
145	1,800	*x*	0	39	*x*	Yegua, Eoc	S	Por	6,947	9	*x*	Yegua	7,495
146	*x*	*x*	0	40–53	*x*	Frio, Olig	S	Por	8,538	18	*x*	Frio	10,010
147	*x*	*x*	0	27	*x*	Miocene	S	Por	4,053	7	*x*	Miocene	7,097
148	2,680	*x*	0	46	*x*	Marginulina, Olig	S	30	6,480	3	D	Vicksburg,	8,943
149	*x*	*x*	0	17–21	*x*	Cap, Mio, Olig	L	Cav Por	500	17	Ds	Cook Mountain	7,461
150	3,100	*x*	0	42–45	*x*	Yegua, Eoc	S	Por	6,803	15	D	Cook Mountain	8,050
151	3,900	*x*	0	40	*x*	Frio, Olig	S	Por	8,105	40	D	Frio	8,795
152	*x*	*x*	0	49	*x*	Wilcox, Eoc	S	Por	8,724	51	*x*	Wilcox	11,505
153	950	*x*	0	37	0.05	Wilcox, Eoc	S	17.5	8,190	30	D	Wilcox	11,734
154	1,450	*x*	0	36–44		Cockfield, Eoc	S	Por	5,150	10	D	Wilcox	11,734
155	*x*	*x*	0	56	*x*	Wilcox, Eoc	S	Por	8,215	*x*	*x*	Wilcox	8,590
156	*x*	*x*	0	*x*	*x*	Mio, Frio, Mio, Olig	S	Por	3,843	*x*	D	Frio	9,210
157	*x*	*x*	*x*	34-57	*x*	Wilcox, Eoc	S	Por	8,133	30	D	Wilcox	11,497
158	574	*x*	0	36-43	*x*	Cockfield, Eoc	S	Por	6,845	20	D	Cook Mountain	7,778
159	*x*	*x*	0	16–31	0.11	Mio, Olig, Yegua, Mio, Olig, Eoc	S	Por	500	100	Ds	Yegua	7,914
160	*x*	*x*	0	37–52	*x*	Frio, Olig	S	Por	7,491	30	D	Frio	8,785
161	1,050	*x*	0	30–42	*x*	Marginulina, Frio, Olig	S	Por	6,409	*x*	Df	Frio	7,007
162	2,085	*x*	0	20–25	*x*	Mio, Frio, Mio, Olig	S	30	3,845	75	Ds	Cockfield	9,474
163	*x*	*x*	0	21–47	0.06	Mio, Olig, Yegua, Mio, Olig, Eoc	S	Por	700	100	Ds	Yegua	4,996
164	1,300	*x*	0	Gas	*x*	Miocene, Mio	S	Por	2,910	30	D	Yegua	8,183
165	*x*	*x*	0	25	*x*	Cap, Mio, Frio, Cap, Mio, Olig	S	Por	800	69	Ds	Frio	7,382
166	2,000	*x*	0	69	*x*	Cockfield, Eoc	S	Por	5,828	12	D	Wilcox	11,023
167	*x*	*x*	0	*x*	*x*	Cockfield, Eoc	S	Por	4,685	19	D	Wilcox	7,759
168	*x*	*x*	0	35	0.02	Frio, Olig	S	Por	7,500	50±	D	Frio	10,200
169	*x*	*x*	0	32	*x*	Miocene	S	Por	4,300	10	Ds	Oligocene	9,267
170	1,570	*x*	0	28–35	*x*	Marginulina, Frio, Olig	S	25	2,500	80	Ds	Yegua	7,521
171	*x*	*x*	0	*x*	*x*	Frio, Olig	S	Por	9,754	5	D	Oligocene	11,854
172	*x*	*x*	0	25–43	0.06	Miocene, Mio	S	*x*	3,600	15–80	D	Vicksburg	8,479
173	*x*	*x*	0			Frio, Olig	S	25	5,000				
174	*x*	*x*	0			Mio, Frio, Mio, Olig	S	25	4,400				
175	*x*	*x*	0			Vicksburg, Olig	S	*x*	7,700				
176	2,490	*x*	*x*	37-41	0.04	Cockfield, Eoc	S	25	5,682	10	D	Wilcox	8,955
177	2,958	*x*	0	32	*x*	Marginulina, Frio, Olig	S	Por	6,550	8	D	Vicksburg	8,497
178	*x*	*x*	0	*x*	*x*	Marginulina, Olig	S	Por		7		Frio	6,646
179	*x*	*x*	0	40	*x*	Yegua, Eoc	S	Por	7,190	3	*x*	Yegua	7,991
180	*x*	*x*	*x*	26-34	*x*	Mio, Olig	S	Por	4,560	15	D	Vicksburg	8,501
181	*x*	*x*	0	28	*x*	Mio, Frio, Mio, Olig	S	Por	354	100±	Ds	Vicksburg	8,518
182	*x*	*x*	0	*x*	*x*	Yegua, Eoc	S	Por	4,719	6	*x*	Yegua	6,016
183	*x*	*x*	0	52	*x*	Yegua, Wilcox, Eoc	S	Por	6,104	15	D	Wilcox	10,012
184	*x*	*x*	0	25	*x*	Frio, Olig	S	Por	5,585	8	Ds	Frio	7,550
185	1,850	*x*	0	38	*x*	Mio, Frio, Mio, Olig	S	Por	3,150	40	Ds	Vicksburg	7,667
186	*x*	*x*	0	41	*x*	Cockfield	S	Por	6,918	5	D	Cook Mountain	7,778
187	3,900	*x*	0	34-37	0.07	Frio, Olig	S	25	8,400	10	D	Frio	9,044
188	*x*	*x*	0	51	*x*	Frio, Olig	S	Por	9,968	28	*x*	Frio	10,796

2400 ft. south of the discovery well, was drilled to 4498 ft. in the Wilcox section. After a series of tests the well finally was completed at 1187 to 1191 ft. in a Reklaw sand, for 55 bbl. of oil through ¼-in. choke plus 5 per cent bottom settlings and water. No other development occurred during 1943.

Citrus Grove, Matagorda County.—Continental Oil Company's No. 1 Anderson was completed on April 28, 1943, for an initial production of 50 million cubic feet of dry gas in a Miocene sand at 3980 to 3990 ft. The well was bottomed at 6555 ft. in basal Miocene. A fairly large gas area may now be outlined from subsurface information, which apparently will include the Collegeport gas field to the southwest, with proven gas reserves of approximately 3900 acres. The producing sands in this area appear to be of lenticular nature and average 15 ft. in thickness. The Continental well was the only development attempted during 1943.

Cottonwood, Liberty County.—William Helis completed his No. 1 Hirsch Est. on Nov. 10, 1943, in a lower Frio sand at 7704 to 7710 ft. for 90 bbl. of 26° gravity oil through a $\frac{7}{64}$-in. choke. Additional development will be required in order to determine the importance of this discovery.

Jackson Pasture, Chambers County.—John G. Mayo's No. 1 J. E. Jackson was completed in a Frio sand at 8102 to 8108 ft. for 90 bbl. of 60.4° gravity oil through a $\frac{3}{16}$-in. choke; gas-oil ratio 19,300:1. Production along this particular trend for the greater part is high-gravity oil and condensate; this discovery does not appear to be an exception. Additional development will be necessary, however, to determine the importance of this discovery.

North Katy, Waller County.—Stanolind Oil & Gas Co. completed its No. 1 G. T. Pattison on March 18, 1943, in a Cockfield-Yegua sand at 6622 to 6625 ft. for an initial production of 154 bbl. of 44.5° gravity oil through a ⅛-in. choke. Tubing pressure was 1800, casing pressure 1900,

TABLE 2.—*Summary of Drilling Operations in Upper Texas Gulf Coast*

Important Wildcats Drilled in 1943

	County	Survey	Total Depth, Ft.	Surface Formation
1	Colorado	G. H. & H. RR, Sec. 15 A245	12,011	Lissie
2	Matagorda	E. L. Holmes Sur. A-203	6,555	Beaumont
3	Liberty	T. & N. O. RR. Sur. 27 A-373	8,205	Beaumont
4	Chambers	John S. Roberts Sur. A-21	9,515	Beaumont
5	Waller	J. M. Bennett Sur. 86, A-285	8,000	Lissie
6	Liberty	M. Duncan Sur. A-29	9,518	Beaumont
7	Wharton	S. P. Middleton Sur. A-269	4,605	Beaumont
8	Wharton	W. C. RR. Co. Sec. 41, A-364	5,523	Beaumont
9	Montgomery	A. Prather Sur. A-427	11,921	Willis
10	Colorado	P. K. Bartheson A-84	10,505	Lissie
11	Wharton	E. T. RR. Co. Sec. 49, A-118	6,160	Beaumont
12	Wharton	S. F. Austin Sur. A-2	4,012	Beaumont
13	Galveston	J. Spillman Sur. A-175	7,781	Beaumont
14	Harris	C. Williams Sur. A-834	8,711	Beaumont
15	Harris	J. B. Stevenson Sur. A-703	5,349	Beaumont
16	Jefferson	F. Valmore Sur. A-54	7,841	Beaumont
17	Matagorda	P. Burnett & A. S. Sojourner Sur.	11,854	Beaumont

gas-oil ratio 2364:1, total depth 8000 ft. This is an important extension to the Katy gas field and indications are that substantial oil production will be obtained from this large structure. Six other oil wells were completed during 1943.

Kirby, Liberty County.—General Crude Oil Co. completed No. 3-B R. A. Welch Fee, March 8, 1943, from a Yegua sand at 8400 to 8430 ft. Initial production was 768 bbl. of 38.8° gravity oil through ¼-in. choke; gas-oil ratio, 876:1, and total depth 9518. This important discovery extends the Yegua production to the southwest flank of the Esperson Dome and provides a substantial increase in reserves. Three other wells were completed during 1943, development still in progress.

Menefee, Wharton County.—Salt Dome Oil Corporation's No. 1-A. G. Menefee et al. was completed Dec. 1, 1943, in a Frio sand at 4540 to 4550 ft. Initial production was 22½ million cubic feet of dry gas daily. There is no field outlet, and the well is now shut in. Present information is not sufficient for estimate of the importance of this discovery. No other wells drilled during 1943.

North Louise, Wharton County.—Continental Oil Co., after drilling its No. 1 Allenson to 5523 ft. completed it in a Frio sand at 4163 to 4166½ ft. for 2¼ million cubic feet gas through ¼-in. choke; tubing pressure, 1680. This is not an important discovery. No other wells were drilled during 1943.

Pinehurst, Montgomery County.—The La Gloria Corporation drilled its No. 1 Grogan-Cochran to 11,921 ft. and completed it in two Wilcox sands at 8760 to 8766 ft. Initial production was 320 bbl. of 38° gravity oil through 3/16-in. choke. At 9700 to 9726 ft., initial production was 120 bbl. of 55° gravity oil through ¼ and 3/16-in. choke series. The discovery well was completed on Jan. 24, 1943. One other well, which failed to produce, completed the drilling program for 1943.

Ramsey, Colorado County.—Cities Service Oil Company's No. 1-F Stephen was completed March 12, 1943, from two horizons in the Wilcox: (1) at 8320 to

TABLE. 2—(*Continued*)

Important Wildcats Drilled in 1943

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. Per Sq. In.		Remarks
			Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Wilcox	Magnolia Petr. Co.	88 Dual 44 comp.	17 35	¼, ⅜ ¼	2,370	2,310	D. Chesterville
2	Miocene	Continental Oil Co.		50	Open flow	1,670	1,670	D. Citrus Grove
3	Vicksburg	Wm. Helis	90		7/64		500	D. Cottonwood
4	Frio	John G. Mayo	90	0.8	⅛	2,900	2,800	D. Jackson Pasture
5	Yegua	Stanolind Oil & Gas Co.	154	0.36	⅛	1,900	1,800	D. North Katy
6	Yegua	General Crude Oil Co.	768		¼	2,000	1,750	D. Kirby
7	Frio	Salt Dome Oil Corp.		22.5	Open flow			D. Menefee Field
8	Vicksburg	Continental Oil Co.		2.25	¼	1,680	1,680	D. North Louise
9	Wilcox	La Gloria Corp.	320 Dual 120 comp.	0.6	3/16 ¼, 3/16	Sealed	900 2,900	D. Pinehurst
10	Wilcox	Cities Service Oil Co.	100 Dual 94 comp.	3.4 3.8	¼ ¼	2,480	2,950	D. Ramsey
11	Frio	Seaboard Oil Co.	185		¼	925	920	D. El Campo
12	Vicksburg	Pan American	72		5/32	140	160	Boling extension
13	Oligocene	Maco Stewart	121		⅛	Sealed	605	Hitchcock extension
14	Yegua	Cities Service Oil Co.	40		7/64	Sealed	1,750	Alief extension
15	Yegua	The Texas Co.	652		¼	Sealed	990	Humble—New Hor.
16	Frio	Gulf Oil Corp.	306 350 Dual		¼ 3/16	400	900	Stowell extension
17	Frio	Superior Oil Co.	132		¼	Sealed	3,100	D. Sugar Valley

TABLE 3.—*Drilling Operations during 1943 and Production during 1942 and 1943, Upper Texas Gulf Coast*

County	1942 Production	1943 Production	Producing Wells	Wells Drilled during 1943					
				Proven Fields			Wildcats		
				Oil	Gas	Dry	Oil	Gas	Dry
Austin	1,587,510	2,674,889	157						
Brazoria	19,369,790	28,914,087	1,214	21	1	22			2
Brazos						6			4
Burleson									2
Chambers	8,616,989	16,186,492	664	17	1	12	1		5
Colorado	82,217	126,907	7	2		1	2		3
Fayette		2,089	1	1					1
Fort Bend	6,669,379	11,579,988	599	17		13			6
Galveston	3,653,126	4,067,078	375	2		3	1		1
Hardin	1,672,041	1,649,492	574	7		3			2
Harris	13,878,307	23,713,566	1,592	22	2	6	2		9
Jasper	2,693					1			1
Jefferson	5,799,526	7,518,517	428	34	2	15	1		10
Liberty	4,802,422	4,757,432	487	6	9		2		2
Madison					1				1
Matagorda	1,719,525	2,789,824	159	22	1	5		2	7
Montgomery	13,514,872	20,148,002	932	1		4	1		2
Newton									
Orange	1,055,265	1,064,781	116	1					
Polk	1,943,228	2,239,434	188			3			
San Jacinto	159,324	898,385	37	23		1			4
Trinity									1
Tyler	840,845	683,578	37	1		3			2
Waller		143,694	10	7	3	6	1		1
Washington	143,659	24,646	54	1					1
Wharton	5,829,774	7,669,365	546	3	1	10	1	2	12
Total	91,340,492	136,852,246	8,177	188	21	114	12	4	79

TABLE 4.—*Fields That Produced One Million or More Barrels of Crude Oil during 1943, Upper Texas Gulf Coast*

Field	County	Year Discovered	1943 Production	Producing Formation
Conroe	Montgomery	1931	19,957,155	Cockfield
Hastings	Brazoria	1934	18,003,529	Frio
Friendswood	Harris	1937	11,456,732	Frio
Thompson	Ft. Bend	1931	10,025,481	Miocene, Frio, Vicksburg
Anahuac	Chambers	1935	8,901,732	Marginulina, Frio
Old Ocean	Brazoria	1934	4,830,749	Frio
Magnet-Withers	Wharton	1936	3,254,909	Frio
North Withers	Wharton	1942	2,731,709	Frio
Fairbanks	Harris	1938	2,716,712	Yegua
Racoon Bend	Austin-Waller	1924	2,674,351	Jackson, Cockfield
Manvel	Brazoria	1931	2,665,524	Miocene, Frio
Barbers Hill	Chambers	1916	2,343,308	Miocene-Frio
Lovell's Lake	Jefferson	1938	2,050,693	Frio
West Columbia	Brazoria	1902	2,049,867	Miocene, Frio
Hull	Liberty	1918	1,886,343	Miocene, Frio, Yegua, Cook Mountain
Stowell	Jefferson	1941	1,876,718	Frio
Sugarland	Ft. Bend	1928	1,836,215	Frio
Amelia	Jefferson	1936	1,670,652	Frio
South Houston	Harris	1935	1,606,138	Miocene, Frio
Segno	Polk	1936	1,601,049	Cockfield, Wilcox
Clear Lake	Harris	1938	1,443,127	Frio
Hardin	Liberty	1935	1,332,209	Yegua
Fannett	Jefferson	1927	1,240,008	Frio
Gillock	Galveston	1935	1,222,500	Frio
Bay City	Matagorda	1934	1,221,148	Frio
Oyster Bayou	Chambers	1941	1,213,856	Frio

8340 ft., initial production was 100 bbl. of 61.8° gravity oil, 6 bbl. salt water and 3½ million cubic feet gas through ¼-in. choke, gas-oil ratio, 29,400:1, and (2) at 8948 to 8970 ft. for an initial production of 94 bbl. of 50.1° gravity oil, 7 bbl. of salt water and 3⁸⁄₁₀ million cubic feet gas through ¼-in. choke. The well was bottomed at 10,505 ft. in Wilcox. The discovery well is the only development to date and does not supply sufficient data for an estimate of its importance.

Sugar Valley, Matagorda County.—The discovery well was drilled by Superior Oil Co. to 11,854 ft. and completed Aug. 15, 1943, in a Frio sand at 9754 to 9759 ft. Initial production was 132 bbl. of 53° gravity oil through ¼-in. choke; tubing pressure, 3100, gas-oil ratio, 38,000:1. The Sugar Valley prospect, a domal-type structure, is already defined to the south and east by dry holes drilled prior to the discovery well. Additional development will be necessary for the determination of the importance of the area, as subsurface data indicate that the most promising part of the structure has not been tested. There is no pipe-line outlet for the field and no other development was carried on during 1943.

NEW PAYS AND EXTENSIONS

At Boling Dome, Wharton County, Pan American's No. 1 Vineyard was completed at 3724 to 3730 ft. Initial production was 72 bbl. The well extended the shallow Frio production to the northeast flank of the Boling Dome.

Maco Stewart extended the Hitchcock field, Galveston County, approximately ½ mile east with the completion of his No. 1 Maco Stewart in a Miocene sand at 5132 to 5137 ft. for 121 bbl. of 29.2° gravity oil through ⅛-in. choke. Total depth was 7780 feet.

The Texas Company discovered a "new pay" on the east flank of the Humble Dome, Harris County, in its No. 52 Stevenson, completed in a Yegua sand at 5320 to 5335 ft. for 325 bbl. of 44° gravity oil through ³⁄₁₆-in. choke. Gas-oil ratio was 548:1.

Other fields where active development programs were carried on during the year include Mercy, in San Jacinto County, a Wilcox pool with 23 new completions. The producing section at Mercy field is of the multiple-sand type and indications are that it will become one of the most important Wilcox fields thus far discovered.

At the Stowell field, Jefferson County, a Frio pool, there were 21 new wells, most of which are dual completions. The Stowell field is unique among Gulf Coast oil fields, being productive on the upthrown side of a large fault roughly at right angles to regional strike. This 1943 development is considered the most important from a reserve standpoint and also may lead to drilling of other faulted areas, which heretofore have been given little promise of worth-while production.

At North Markham, Matagorda County, a Frio pool, there were 12 new completions; at Lovell's Lake, Jefferson County, 11 new completions and at Clodine, Fort Bend County, 10 new Yegua producers.

A lower Frio sand of high distillate yield at Double Bayou, Chambers County, was also a feature of the year.

Oil and Gas Development and Production in North Texas for the Year 1943

By R. B. Gilmore,* Junior Member A.I.M.E.

The North Texas district, as herein defined, includes the counties of Archer, Baylor, Clay, Cooke, Foard, Hardeman, Jack, Knox, Montague, Wichita, Wilbarger, and Young. Jack and Young Counties are included for the first time so that this district will correspond with District No. 9 of the Texas Railroad Commission. This area covers generally the crest and south flank of a system of buried mountains known as the Red River uplift. The oil and gas accumulations along this feature are in traps, which, although localized by structures incident to the regional uplift, usually are modified by stratigraphic changes in the sediments.

The structural deformation caused by the Red River uplift is modified by the Bend arch, which is a broad anticline plunging northward from the Llano uplift in central Texas through Young and into Archer Counties. The fields in southern Archer, southeastern Baylor, southwestern Clay, and western Jack Counties are on the extreme north end and along the flanks of the Bend arch and have generally the same type of oil and gas accumulation as the other fields in this district. Recent exploration has been along the flanks of the Fort Worth syncline, which is east of the Bend arch and south of the Red River uplift and extends into southeastern Clay and southwestern Montague Counties and along the eastern part of Jack County. The larger part of past oil and gas production has come from Pennsylvanian strata, with less important amounts from the Permian, and minor quantities from the Mississippian and Ordovician.

Developments during 1943

About 1100 wells were drilled in the district during 1943 and more than 500 oil wells were completed, an increase from 1942 of approximately 12 per cent in the number of successful drilling operations of the total wells drilled. The addition of Jack and Young Counties to this district accounts for part of this increase, almost 150 wells being completed in the two counties.

Production increased slightly over the previous year as a result of an increase in the number of producing wells and a greater demand for this high-gravity, sweet crude oil. The average depth of discovery wells was about 400 ft. deeper than in 1942. Although more discoveries produced from horizons below the base of the Strawn series than from those above the Strawn, the deeper horizons, including the Bend series of the Pennsylvanian, the Mississippian limestone and Ellenburger of the Ordovician, largely were disappointing from the viewpoint of major additions to oil reserves.

The largest single addition to the reserves was in the basal Strawn sand in the Walnut Bend field, Cooke County. During the year, 31 wells were completed, both in the field and as extensions. The most active area was Jack County, in which five fields or potential fields were discovered, although only 44 oil wells were completed.

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Although deeper exploration in the district has been somewhat disappointing, continued development of older horizons is expected in the search for larger additions to oil reserves. The number of wildcat wells successfully completed during the past year, and the extensions to older producing areas, together with firm demand for crude oil from this district, indicate continuance of present rates of exploratory work in this area during the coming year.

ACKNOWLEDGMENTS

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(Tables on pages 494–503)

TABLE 1.—*Oil and Gas Production in North Texas District*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[e]		Producing Days, 1943[d]	Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		Completed to End of 1943	1943	
								Completed	Abandoned
	Archer County:								
1	Anarene	1924	8,000	[1]	153,555	365	1,027*x*	0	14
2	Blewett	1940	100	110,752	28,132	365	12	0	0
3	Browning	1942	200	20,867	18,341	249	5	4	0
4	Burns-Ickert	1943	40	11,214	11,214	135	1	1	0
5	Chalk Hill (deep)	1931	650	3,175,034	68,058	365	*x*	1	1
6	Colgan	1939	100	119,469	33,359	249	9	0	0
7	Cooper	1942	240	66,740	60,147	342	6	5	0
8	Fuller	1943	40	510	510	56	1	1	0
9	Hull-Silk	1938	7,000	15,016,787	3,905,845	249	444	1	4
10	Kadane, deep	1939	400	511,696	181,916	328	19	2	0
11	Kadane, shallow	1939	80	122,057	55,956	328	10	1	0
12	Little Wichita	1943	120	37,864	37,864	214	3	3	0
13	Mankins	1939	500	768,420	181,268	328	14	0	0
14	McCrory	1938	20	45,502	5,999	365	1	0	0
15	Meade	1940	50	23,141	3,578	365	7	0	0
16	Moer	1938	20	24,348	3,395	365	1	0	0
17	Oldham	1925	600	[1]	71,061	365	114*x*	0	1
18	Pan-Taylor	1941	80	14,262	10,751	365	3	2	0
19	Scotland	1940	1,000	729,418	391,893	328	36	10	0
20	Vogtsberger	1940	400	168,042	88,466	365	10	7	0
21	All other fields	1911	*x*	[1]	2,182,900		*x*	84	174
22	Total Archer County		*x*	145,476,427	7,494,208		7,7*xx*	122	194
	Archer and Wichita Counties:								
23	Jackson	1938	300	271,703	30,415	365	22	0	0
	Baylor County:								
24	Portwood	1924	600	5,093,189	124,621	365	188	0	3
25	Rendham	1940	600	222,971	74,634	249	15	1	2
26	Seymour	1939	1,600	1,300,646	398,047	273	39	6	0
27	Total Baylor County		2,800	6,616,806	597,302		242	7	5
	Clay County:								
28	Antelope (incl. Mississippi)	1939	900	1,348,323	596,113	365	55	1	0
29	Burns-Browning	1939	320	224,280	35,594	249	7	0	1
30	Burns-Midway	1943	80	40,486	40,486	184	3	3	0
31	Costley	1939	40	83,832*x*	19,146	365	14	2	0
32	Edrington	1932	600	1,504,878*x*	195,408	365	132	13	0
33	Halsell	1939	500	525,206	172,505	249	13	2	0
34	Hapgood	1940	120	198,430	68,990	328	3	0	0
35	Howard	1940	40	3,851	3,558	365	1	0	0
36	Joy	1940	700	433,298	304,005	365	16	10	0
37	Kinder	1939	40	19,049	8,765	249	1	0	0
38	Knox-Finley	1923	700	799,255	168,709	365	121	10	2
39	McInniss	1940	400	601,423	198,773	365	86	8	1
40	Nebraska	1922	140	[1]	24,217	249	4	1	0
41	New York City	1941	400	290,535	133,460	249	10	0	0
42	Petrolia	1902	3,000	[1]	83,417	365	*x*	10	4

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[b] Footnotes to column heads and explanation of symbols are given on page 270.

[1] Included in county total.

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943		Character of Oil[i]	Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil										
	Flowing	Artificial Lift	Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
1	0	561	40	Cisco, Pen	S	Por	1,000	*x*	A	Ellenburger	5,426
2	0	12	38	Cisco, Pen	S	Por	1,425	*x*	ML	Cisco	1,557
3	5	0	41	Strawn, Pen Ellenburger, Ord	S DL	Por Por	4,706 5,321	*x*	*x*	Ellenburger	5,414
4	0	1	41	Bend, Pen	L	Por	4,468	*x*	*x*	Mississippian	5,165
5	1	34	42	Canyon, Pen Strawn, Pen Bend, Pen	S S L	Por Por Por	2,200 3,600 4,876	*x*	A	Ellenburger	5,748
6	0	9	40	Cisco, Pen	S	Por	1,453	8	MC	Cisco	1,500
7	5	1	43	Detrital, *x*	DCgl	Por	4,910	30	*x*	Ellenburger	5,028
8	0	1	47	Bend, Pen	L	Por	5,360	*x*	*x*	Ellenburger	5,507
9	125	314	43	Strawn, Pen Bend, Pen	S & L L	Por Por	3,800 4,620	20 10	A	Ellenburger	5,272
10	14	5	42	Strawn, Pen	S	Por	4,337	10	A	*x*	4,901
11	0	10	42	Cisco, Pen	S	Por	1,630	8	AM	*x*	4,901
12	3	0	42	Bend, Pen	L	Por	4,878	*x*	*x*	Ellenburger	5,623
13	6	8	43	Bend, Pen	L	Por	4,660	30	A	*x*	4,918
14	0	1	41	Bend, Pen	L	Por	4,735	20	N	*x*	5,159
15	0	7	38	Cisco, Pen	S	Por	954	5	*x*	Cisco	1,407
16	0	1	40	Strawn, Pen	S	Por	4,135	3	*x*	Ellenburger	5,433
17	0	64	40	Cisco, Pen	S	Por	1,040	*x*	A	*x*	5,295
18	1	2	43	Cisco, Pen Chappel, Mis Ellenburger, Ord	S L D	Por Por Por	1,638 4,927 4,937	*x*	*x*	Ellenburger	4,973
19	31	5	42	Strawn, Pen Bend, Pen Chappel, Mis	S L L	Por Por Por	4,016 5,042 5,550	10	A	Ellenburger	5,850
20	8	2	41	Strawn, Pen	S	Por	4,656	15	*x*	Ellenburger	5,335
21	0	2,548									
22	194	3,586									
23	0	22	*x*	Canyon, Pen	L	Por	2,600	10	*x*	Canyon	2,700
24	0	124	36	Gunsight, Pen	S	Por	1,340	*x*	ML	Strawn	4,265
25	0	13	31	Canyon, Pen	L	Por	3,025	*x*	M	Strawn	4,326
26	0	38	36	U. Canyon, Pen	L	Por	2,525	20	N	Ellenburger	5,598
27	0	175									
28	39	16	40	Strawn, Pen Bend, Pen Chappel, Mis	S L L	Por Por Por	3,190 5,451 5,670	25 *x* *x*	AM	Ellenburger	6,100
29	1	5	44	Strawn, Pen	S	Por	4,430	20	A	Ellenburger	6,014
30	3	0	45	Chappel, Mis	L	Por	6,010	*x*	*x*	Ellenburger	6,298
31	0	14	40	Cisco, Pen	S	Por	1,035	18	ML	Cisco	1,406
32	0	131	38	*x*, Pen Cisco, Pen	S S	Por Por	325 1,090	15	N	*x*	2,064
33	4	9	41	Canyon, Pen Strawn, Pen	L S	Por Por	2,604 3,656 4,720	*x*	A	Ellenburger	6,048
34	3	0	45	Bend, Pen	Cgl	Por	5,972	20	*x*	Ellenburger	6,538
35	0	1	44	Bend, Pen	L	Por	5,460	15	*x*	Bend	5,606
36	6	10	41	Strawn, Pen Chappel, Mis	S L	Por Por	3,960 5,905	*x*	A	Ellenburger	6,213
37	0	1	37	Strawn, Pen	S	Por	4,130	15	*x*	Bend	5,527
38	0	118	40	*x*, Per *x*, Pen	S S	Por Por	280 1,110	10	A	Cisco	1,716
39	0	83	40	*x*, Per *x*, Pen	S S	Por Por	250 1,070	10	A	Cisco	1,404
40	2	1	42	Bend, Pen	L	Por	5,746	10	A	Ellenburger	6,098
41	9	1	45	Strawn, Pen Chappel, Mis	S L	Por Por	4,911 6,180	*x*	*x*	Ellenburger	6,837
42	0	388	30	*x*, Per *x*, Pen	S S	Por Por	230 760 1,000 1,720	12 10 10 15	AM	Pre-Cambrian	4,289

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c] To End of 1943	Oil Production Total, Bbl.[c] During 1943	Producing Days, 1943[d]	Number of Oil and/or Gas Wells[f] Completed to End of 1943	Number of Oil and/or Gas Wells[f] 1943 Completed	Number of Oil and/or Gas Wells[f] 1943 Abandoned
43	Ross	1939	840	361,786	118,255	249	21	1	0
44	Shumake	1937	550	759,877	86,030	365	81	0	11
45	Spring	1941	80	168,881	100,332	328	3	1	0
46	Stephens	1943	80	33,426	33,426	229	2	2	0
47	Taylor-Clay (incl. Boddy)	1938	600	676,647	237,935	365	115	17	3
48	Watson	1942	600	109,931	75,390	350	14	4	2
49	Worsham	1923	200	[1]	28,518	365	13	0	0
50	Wright-Barry	1926	60	[1]	2,940	365	11	0	0
51	Wynn	1943	40	3,502	3,502	35	1	1	0
52	Abandoned Fields	1940	80	5,654	1,819		3	1	1
53	Total Clay County		11,110	15,968,012	2,741,293		1,6*xx*	87	25
	Cooke County:								
54	Anderson	1935	880	4,108,399	272,560	365	128	0	0
55	Big Indian	1924	20	[1]	2,944	365	2	0	0
56	Bindel	1941	80	111,289	62,472	298	7	1	0
57	Bulcher	1926	580	[1]	182,828	365	168	0	0
58	Dangle	1943	40	2,292	2,292	46	1	1	0
59	Fleitman	1943	80	3,326	3,326	153	7	7	0
60	Huggins[2]	1929	160	[1]	1,196	121	30	0	17
61	Muenster	1926	1,900*x*	[1]	597,029	365	6*xx*	2	18
62	Osburn	1941	10	10,434	5,706	249	1	0	0
63	Pilot Point	1930	80	[1]	938	365	8	0	0
64	Talbott	1936	40	37,856	3,327	365	6	0	1
65	T.C.U	1939	300	207,135	52,666	365	53	0	0
66	Trew	1936	300	952,426	52,945	365	49	0	6
67	Voth	1938	650	706,476	114,819	365	69	7	1
68	Walnut Bend	1938	3,000	5,900,787	2,009,845	365	161	31	0
69	Wheelock	1928	100	88,503*x*	3,326	365	11	0	0
70	Wilson	1941	140	63,526	26,100	328	8	0	0
71	Total Cooke County		8,360	29,218,020	3,394,319		*x*	49	45
	Foard County:								
72	Johnson	1933	380	1,749,436	53,651	365	16	0	0
73	Thalia	1927	180	350,258	11,063	365	13	0	0
74	Abandoned fields	1940	120	17,353	0		5	0	0
75	Total Foard County		680	2,117,047	64,714		34	0	0
	Jack County:								
76	Ellis	1942	500	95,047	95,047	365	11	10	0
77	Hoefle	1941	800	346,054	214,744	328	20	7	2
78	McDonald	1943	160	20,218	20,218	229	3	3	0
79	Meyers	1938	150	61,357	30,406	266	6	2	0
80	Peek	1943	40	15,875	15,875	214	1	1	0
81	Pursley	1943	40	658	658	31	1	1	0
82	Taubert-McKee	1942	40	6,599	3,045	365	1	0	0
83	Webb	1941	40	3,516	842	365	1	0	0
84	Weir	1943	80	6,443	6,443	148	2	2	0
85	Wolfe	1943	40	12,800	12,800	310	1	1	0
86	Worsham-Steed	1942	80	43,580	26,999	328	2	0	0
87	All other fields	1907	*x*	21,867,382	1,516,636		*x*	17	51
88	Total Jack County		*x*	22,479,529	1,943,713		*x*	44	53

[2] Field abandoned, 1943.

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943		Character of Oil[i]	Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil		Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift									
43	12	9	42	Strawn, Pen Bend, Pen	S L	Por Por	4,050 5,350	*x* 40	A	Ellenburger	5,846
44	0	70	*x*	Cisco, Pen	S	Por	1,130	15	*x*	Cisco	1,945
45	1	2	48	Bend, Pen	L	Por	5,588	*x*	*x*	Ellenburger	6,262
46	2	0	48	Chappel, Mis	L	Por	6,011	*x*	*x*	Mississippian	6,049
47	0	111	40	Cisco, Pen	S	Por	200 1,120	10 15	A	Cisco	1,852
48	5	7	41	Strawn, Pen Bend, Pen	S L	Por Por	3,640 5,452	*x*	A	Ellenburger	6,051
49	0	8	38	Strawn, Pen Bend, Pen Ellenburger, Ord	S L D	Por Por Por	3,400 3,925 5,588 5,780	10 20 *x* *x*	*x*	Ellenburger	6,220
50	0	5	*x*	*x*, Pen	S	Por	840	*x*	*x*	Strawn	4,112
51	1	0	45	Chappel, Mis	L	Por	6,153	*x*	*x*	Ellenburger	6,795
52	0	0									
53	88	990									
54	0	124	41	U. Strawn, Pen L. Strawn, Pen	S S	Por Por	1,605 1,950	10	AM	*x*	2,710
55	0	1	47	Strawn, Pen	S	Por	3,518	11	*x*	Strawn	3,919
56	2	5	38	Strawn, Pen Ellenburger, Ord	S DL	Por Por	1,885 3,242	10 5	A	Ellenburger	3,247
57	0	145	*x*	Strawn, Pen Ellenburger, Ord	S DL	Por Por	1,125 1,403	10	MC	*x*	2,042
58	1	0	37	Ellenburger, Ord	DL	Por	2,179	*x*	*x*	Ellenburger	2,183
59	0	7	40	Strawn, Pen	S	Por	1,148	*x*	*x*	*x*	1,702
60	0	0	*x*	Strawn, Pen	S	Por	1,150	10	N	*x*	2,001
61	0	591	33	Cisco, Pen Canyon, Pen Strawn, Pen	S S S,L	Por Por Por	707 990 1,585	10 *x* 15	A	Ellenburger?	1,960
62	0	1	*x*	Strawn, Pen	S	Por	2,309	10	*x*	Strawn	2,320
63	0	2	25	Cisco, Pen	S	Por	1,502	*x*	*x*	*x*	1,652
64	0	3	40	Strawn, Pen	S	Por	1,650	5	N	*x*	3,100
65	0	50	30	Strawn, Pen	S	Por	1,125	8	A	*x*	2,163
66	0	43	37	Strawn, Pen	S	Por	1,475	8	AM	*x*	2,095
67	0	63	38	Ellenburger, Ord	L	Por	1,725	10	*x*	Ellenburger	1,793
68	26	135	34	U. Strawn, Pen L. Strawn, Pen Simpson, Pen Ellenburger, Ord	S S S L	Por Por Por Por	4,108 5,141 5,496 5,206 5,413	7 20 20 30 30	N	Ellenburger	6,110
69	0	8	*x*	*x*, Pen	S	Por	1,306	*x*	N	*x*	1,397
70	0	7	41	Strawn, Pen	S	Por	2,221	10	AM	Strawn	2,380
71	29	1,185									
72	1	9	50	Canyon, Pen	L	Por	3,600	*x*	A	Pre-Cambrian	5,003
73	0	5	39	Thalia, Pen Cisco, Pen	S L	Por Por	*x* 2,500	*x*	*x*	Pre-Cambrian	2,550
74	0	0									
75	1	14									
76	11	0	43	Bend, Pen	L	Por	4,760	*x*	A	Ellenburger	5,809
77	12	6	43	Strawn, Pen Bend, Pen	S L	Por Por	2,712 4,850	*x*	A	Ellenburger	6,177
78	2	1	33	Strawn, Pen	S	Por	3,518	20	*x*	Ellenburger	6,040
79	0	6	*x*	Strawn, Pen	S	Por	2,401	10	*x*	*x*	3,804
80	1	0	40	Bend, Pen	L	Por	4,579	10	*x*	Bend	4,589
81	0	1	40	Mississippi, Mis	L	Por	5,443	*x*	*x*	Ellenburger	6,011
82	0	1	42	Ellenburger, Ord	D	*x*	6,388	*x*	*x*	Ellenburger	6,501
83	1	0	41	Strawn, Pen	S	Por	2,892	16	*x*	Ellenburger	6,175
84	0	2	41	Strawn, Pen	S	Por	2,322	10	*x*	Ellenburger	6,011
85	1	0	40	Bend, Pen	L	Por	4,375	*x*	*x*	Ellenburger	5,631
86	0	2	41	Strawn, Pen	L	Por	4,694	*x*	*x*	*x*	4,822
87	34	678									
88	62	697									

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		Completed to End of 1943	1943	
								Completed	Abandoned
	Montague County:								
89	Beck	1933	300	2,157,348*x*	104,398	365	69	2	0
90	Benson	1941	100	61,752	16,545	249	4	0	1
91	Bonita	1940	380	878,203	261,367	328	20	0	1
92	Bowers	1939	850	1,072,006	349,129	249	39	3	0
93	Chapman and McFarlin	1941	20	45,397	19,682	328	1	0	0
94	Clingingsmith	1941	200	139,078	48,377	328	6	1	1
95	Denver	1943	40	12,985	12,985	189	1	1	0
96	Eanes	1942	40	3,770	2,938	365	1	0	0
97	Forestburg	1942	300	211,773	116,562	328	7	0	1
98	Hildreth	1942	600	180,373	175,410	354	14	13	0
99	Holt	1936	240	838,965	49,695	365	37	0	0
100	Hultz and Owens	1940	80	95,513	14,461	365	5	0	1
101	Illinois-Bend	1942	200	44,796	42,396	365	4	3	0
102	Ketchum	1942	80	3,296	2,841	365	2	1	0
103	Mueller	1942	200	101,110	72,139	328	5	3	0
104	Nocona	1918	3,200	31,768,951*x*	1,025,156	365	950*x*	1	15
105	Ringgold	1940	520	633,969	262,908	328	13	0	0
106	Rogers and Rogers (incl. Dodson)	1939	1,100	2,120,602	481,831	249	52	5	0
107	Sanders	1942	160	164,632	85,417	328	4	0	0
108	Seitz	1933	300	1,361,663	192,081	365	52	0	0
109	Seitz-King	1942	40	3,385	2,216	365	1	0	0
110	Stoneburg	1941	200	59,978	44,039	249	5	3	0
111	Thomas	1941	20	4,142	1,194	365	1	0	0
112	Turner	1941	40	21,621	7,260	365	1	0	0
113	Abandoned fields	1940	80	6,802	234		2	0	1
114	Totals Montague County		9,290	41,992,110	3,391,261		1,263*x*	36	21
	Wichita County:								
115	Airport	1943	80	10,805	10,805	184	2	2	0
116	Asylum	1938	80	102,891	15,104	365	3	0	0
117	Davidson	1943	80	15,140	15,140	153	2	2	0
118	K.M.A.-Ellenburger	1940	6,000	5,724,599	2,917,102	365	169	7	5
119	K.M.A.-Strawn	1931	30,000	51,898,884	7,866,503	251	1,6*xx*	14	9
120	Oates	1940	140	259,037	58,849	365	37	0	0
121	Underwood	1939	60	73,057	8,650	365	10	0	0
122	West	1943	200	33,813	33,813	153	5	5	0
123	All other fields	*x*	*x*	328,192,234	3,654,553		*x*	35	231
124	Total Wichita County		*x*	386,310,460	14,580,519		*x*	65	245
	Wilbarger County:								
125	Castleberry	1937	200	619,877	105,161	249	24	0	0
126	Consolidated	1939	700	1,528,021	250,784	249	56	4	2
127	Electra-Ellenburger	1941	80	27,511	9,546	249	2	0	0
128	Fargo	1940	2,000	2,259,017	1,170,369	365	50	5	0
129	Fluhman	1926	200	[1]	12,321	365	22	0	0
130	Harrold	1941	320	210,605	97,736	249	13	4	0
131	King	1939	80	77,585	5,101	365	10	0	0
132	King-Lawson	1936	20	29,829	6,436	365	2	0	0
133	King-Waggoner	1936	120	138,834	9,757	365	10	0	0

TABLE I.—(*Continued*)

	Wells Producing[g] Dec. 1943		Character of Oil[i]	Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil										
Line Number	Flowing	Artificial Lift	Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
89	0	55	39	Canyon, Pen Strawn, Pen	SL S	Por Por	1,480 2,471	x	AL	x	2,484
90	2	1	44	Bend, Pen	L	Por	5,840	10	x	Ellenburger	6,014
91	11	8	40	Strawn, Pen Bend, Pen	S S	Por Por	5,240 5,443	9 15	A	Ellenburger	6,975
92	9	27	39	Canyon, Pen Strawn, Pen	L S	Por Por	2,020 2,880	10 15	A	Granite	4,300
93	0	1	44	Strawn, Pen	S	Por	4,840	x	x	Ellenburger?	6,008
94	0	5	40	Bend, Pen	Cgl	Por	6,120	10	N	Bend	6,131
95	0	1	40	Bend, Pen	L	Por	6,073	x	x	Ellenburger	7,766
96	0	1	41	Bend, Pen	Cgl	Por	5,828	x	x	Ellenburger	7,073
97	3	3	40	Bend, Pen	L	Por	7,176	x	x	Simpson	8,147
98	14	0	40	Bend, Pen Simpson, Ord	Cgl DS	Por Por	6,050 7,170	x	x	Ellenburger	7,413
99	0	37	32	Canyon, Pen	LS	Por	1,700	5	AM	Granite	3,648
100	1	0	45	Bend, Pen	L	Por	6,016	x	x	Bend	6,070
101	0	4	30	Strawn, Pen	S	Por	3,463 3,860	x	x	Strawn	4,982
102	0	2	37	Strawn, Pen	S	Por	3,338	6	A	Ellenburger	7,506
103	5	0	40	Bend, Pen Simpson, Ord	L S	Por Por	6,015 7,200	x	A	Ellenburger	7,270
104	0	796	32	Cisco, Pen Canyon, Pen Strawn, Pen	S L S	Por Por Por	230 x x	x	A	Granite	3,024
105	5	7	47	Bend, Pen Ellenburger, Ord	Cgl DL	Por Por	5,690 5,800	10 20	N	Ellenburger	6,092
106	24	27	43	Strawn, Pen Bend, Pen	S & L Cgl & L	Por Por	4,280 5,125	20 15	A	Ellenburger	6,988
107	2	2	36	Bend, Pen	Cgl	Por	5,962	20	x	Ellenburger	6,860
108	0	49	37	Canyon, Pen Strawn, Pen	L S	Por Por	1,610 2,015	6	AL	x	2,741
109	0	1	38	Canyon, Pen	S	Por	1,630	x	x	x	4,066
110	2	3	44	Bend, Pen	Cgl	Por	6,233	8	x	Viola	6,610
111	0	1	x	Strawn, Pen	S	Por	3,023	x	x	Ellenburger	4,646
112	1	0	41	Bend, Pen	Cgl	Por	6,222	12	x	Ellenburger	7,501
113	0	0									
114	79	1,031									
115	0	2	44	Strawn, Pen	S	Por	4,415	x	x	Ellenburger	5,401
116	0	3	42	Smithwick, Pen	L	Por	5,076	20	x	Ellenburger	5,418
117	0	2	47	Ellenburger, Ord	D	Por	5,350	x	x	Ellenburger	5,364
118	114	50	42	Ellenburger, Ord	DL	Por	4,330	30	AC	Ellenburger	4,881
119	905[3]	702[3]	40	Strawn, Pen	SL	Por	3,500	25	AC	Ellenburger	4,881
120	0	37	x	Cisco, Pen	S	Por	1,313	12	N	Cisco	1,340
121	0	9	40	Cisco, Pen	S	Por	1,200	6	x	Cisco	1,482
122	5	0	40	Strawn, Pen	S	Por	4,228	x	x	Ellenburger	5,687
123	4	5,318									
124	1,028	6,128									
125	6	18	36	Cisco, Pen Canyon, Pen	S L	Por Por	2,170 3,190	9 15	x	x	3,750
126	9	44	40	Cisco, Pen Strawn, Pen Bend, Pen Ellenburger, Ord	S LS L DL	Por Por Por Por	1,750 3,750 4,025 4,300	10 20 40 17	A	Ellenburger	4,381
127	0	2	43	Ellenburger, Ord	L	Por	3,627	8	x	Ellenburger	3,635
128	3	47	42	Cisco, Pen Canyon, Pen Strawn, Pen	S L S	Por Por Por	3,200 3,970 4,370	25 15 15	A	Ellenburger	6,717
129	0	13	40	Cisco, Pen	S	Por	2,040	20	x	x	2,867
130	1	12	41	Canyon, Pen	S	18	3,160	12	x	x	4,412
131	0	8	38	Cisco, Pen	S	Por	1,220	x	x	x	2,671
132	0	2	x	x, Pen	S	Por	1,990	10	x	Canyon	2,805
133	0	10	40	Cisco, Pen	S	Por	1,535	10	x	Cisco	1,784

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[3] Includes 102 wells used for gas input. Allowable for these wells produced by other wells.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		Completed to End of 1943	1943 Completed	1943 Abandoned
134	Lawson	1935	80	288,484	18,680	365	15	0	0
135	Main	1943	40	2,048	2,048	31	1	1	0
136	Millham	1925	100	[1]	4,528	365	14	0	1
137	Phillips-King	1938	160	149,607	28,216	365	7	1	2
138	Potts	1942	80	33,004	10,825	249	3	0	0
139	Rock-Crossing-Canyon	1940	450	533,667*x*	208,046	249	32	1	0
140	Rock-Crossing-Ellenburger	1941	300	157,117	94,096	293	7	1	0
141	Rogers-McCrary	1943	100	17,578	17,578	214	5	5	0
142	Waggoner Ranch	1943	200	14,805	14,805	150	5	5	0
143	Wilkinson	1943	40	8,945	8,945	214	1	1	0
144	Zenith	1930	80	[1]	4,463	365	12	0	0
145	All other fields	1915	*x*	[1]	1,814,984		*x*	10	24
146	Total Wilbarger County		*x*	83,242,553	3,894,425		*x*	38	29
	Young County:								
147	Allar	1941	300	77,990	68,017	249	15	12	0
148	Barrett	1943	40	12,626	12,626	122	1	1	0
149	Blount	1940	80	21,303	2,612	249	2	0	0
150	Burns-Larrimore	1941	160	72,152	21,576	249	4	0	0
151	Burns-Ragland	1941	220	126,678	105,276	354	6	1	0
152	Daws	1942	40	8,892	5,576	249	1	0	0
153	Dean	1936	400	256,194*x*	1,864	284	12	0	7
154	Fish Creek	1937	400	138,817	21,370	365	9	2	2
155	Garvey	1941	80	34,468	22,395	249	2	1	0
156	Holbert	1942	40	27,048	26,554	249	1	0	0
157	James	1928	3,200	1,939,073*x*	140,763	249	90	0	3
158	Kerlyn-Loving	1940	100	47,616	15,248	249	4	0	0
159	Knight	1938	500	645,696	46,784	284	25	0	5
160	Knox (incl. Bennett and Briar Creek)	1931	3,000	[1]	426,075[4]	249	116	7	6
161	Lupton McLester	1931	1,000	1,044,429*x*	141,464	249	57	8	1
162	Morrison	1943	40	8,397	8,397	153	1	1	0
163	Murray	1937	360	94,459	93,280	344	9	4	0
164	Newcastle	1941	200	55,883	19,632	365	5	0	0
165	Padgitt	1942	380	123,532	92,142	342	5	2	0
166	Sewell	1938	1,600	1,285,991*x*	247,052[4]	249	63	0	2
167	Taylor-Young	1941	40	12,719	2,794	249	2	0	0
168	Williamson	1934	240	172,845	53,437	249	6	1	0
169	Wray	1938	160	189,553	29,684	249	4	0	0
170	All other fields	1917	*x*	[1]	1,930,193	*x*	*x*	58	93
171	Total Young County		*x*	81,324,007	3,534,811		*x*	98	119
172	Total North Texas District		*x*	815,016,674	41,666,980		*x*	546	736

[4] Includes distillate production.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943		Character of Oil[i]	Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil										
	Flowing	Artificial Lift	Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
134	0	15	41	Cisco, Pen	S	Por Por	1,310 2,296	20 10	*x*	*x*	3,174
135	0	1	38	Canyon, Pen	L	Por	2,786	10	*x*	Granite Wash	4,725
136	0	8	*x*	Cisco, Pen	S	Por	1,270	*x*	*x*	*x*	2,725
137	1	4	38	Cisco, Pen Canyon, Pen	S L	Por Por	1,900 2,500	*x*	*x*	*x*	3,370
138	0	2	42	Strawn, Pen Ellenburger, Ord	S DL	Por Por	4,053 4,506	11 11	*x*	Ellenburger	4,583
139	10	22	*x*	Canyon, Pen	L	Por	3,015	10	*x*	Ellenburger	3,815
140	4	3	39	Ellenburger, Ord	DL	Por	3,770	10	*x*	Ellenburger	3,852
141	0	5	39	Cisco, Pen	S	Por	1,486	10	N	*x*	2,003
142	5	0	41	Ellenburger, Ord	DL	Por	4,390	20	A	Ellenburger	4,509
143	0	1	40	Bend, Pen	L	Por	5,780	*x*	*x*	Ellenburger	6,133
144	0	8	*x*	Cisco, Pen	S	Por	2,190	15	*x*	*x*	2,863
145	0	1,422									
146	39	1,647									
147	10	5	38	Canyon, Pen Strawn, Pen Bend, Pen	L S L	Por Por Por	1,686 2,720 3,550	11 15 20	A	Bend	3,607
148	1	0	*x*	Mississippi, Mis	L	Por	5,180	*x*	*x*	Ellenburger	5,530
149	0	2	40	Strawn, Pen	S	Por	3,051	10	*x*	Bend	4,683
150	1	3	45	Mississippi, Mis	L	Por	4,872	*x*	A	*x*	5,100
151	4	1	42	Mississippi, Mis	L	Por	4,850	*x*	A	Ellenburger	5,288
152	0	1	38	Bend, Pen	L	Por	3,847	15	*x*	Ellenburger	4,920
153	0	4	41	Bend, Pen	L	Por	3,746	12	*x*	Ellenburger	4,815
154	0	5	36	Bend, Pen	L	Por	3,350	*x*	N	Bend	3,637
155	0	2	43	Bend, Pen	L	Por	4,280	*x*	*x*	Ellenburger	5,437
156	0	1	39	Bend, Pen	L	Por	3,857	*x*	*x*	Ellenburger	5,276
157	16	35	38	Bend, Pen Mississippi, Mis	L L	Por Por	3,867 4,275 4,810	*x*	A	Ellenburger	5,442
158	0	4	42	Strawn, Pen Bend, Pen	S L	Por Por	2,906 4,050	*x*	A	Ellenburger	5,292
159	5	7	38	Bend, Pen	L	Por	3,760	*x*	A	*x*	4,323
160	36	46	41	Strawn, Pen Bend, Pen Mississippi, Mis	S L L	Por Por Por	2,750 3,900 4,766	*x*	A	*x*	4,853
161	33	12	40	Bend, Pen	L	Por	3,800	*x*	A	*x*	4,833
162	1	0	43	Mississippi, Mis	L	Por	4,439	15	*x*	*x*	4,737
163	7	0	41	Bend, Pen Mississippi, Mis	L L	Por Por	3,635 4,181 4,466	10 14 *x*	*x*	*x*	4,839
164	1	4	40	Bend?, Pen	SL	Por	3,970	*x*	*x*	*x*	4,977
165	5	0	44	Mississippi, Mis	L	Por	4,748	*x*	*x*	Ellenburger	5,001
166	23	15	44	Strawn, Pen Bend, Pen	S L	Por Por	2,476 3,925 4,260	*x*	A	Ellenburger	4,636
167	1	1	44	Bend, Pen	L	Por	4,250	*x*	*x*	Bend	4,486
168	0	6	45	Strawn, Pen Bend, Pen Mississippi, Mis	S L L	Por Por Por	2,940 3,960 5,000	*x*	*x*	Ellenburger	5,246
169	2	1	41	Bend, Pen Mississippi, Mis	L L	Por Por	3,960 4,250 4,595	*x*	*x*	Ellenburger?	4,891
170	35	2,092									
171	181	2,247									
172	1,701	17,722									

TABLE 2.—*Summary of Drilling Operations in North Texas*

DISCOVERIES, EXTENSIONS, AND IMPORTANT WILDCATS DRILLED DURING 1943

	Field	County	Drilled By	Well No. and Farm
1	Browning	Archer	Perry Browning	Fee No. 3
2	Burns-Ickert	Archer	L. T. Burns	A. F. Ickert No. 14
3	Fuller	Archer	Tom B. Medders	O. M. Fuller No. 1
4	Little Wichita	Archer	Phillips Petr. Co.	Wilson-Luke No. 1
5	Pan-Taylor	Archer	McCarthy & Coleman	W. H. Taylor No. 1-A
6		Archer	G. W. Cooper	J. R. Parkey No. 1
7	Burns-Midway	Clay	L. T. Burns	J. P. Thompson No. 1
8	Ross	Clay	Continental Oil Co.	O. O. Ross No. 11
9	Stephens	Clay	Continental Oil Co.	T. J. Stephens No. 1
10	Wynn	Clay	Shell Oil Co.	R. F. Wynn No. 1
11		Clay	Roy Lee, Tr.	C. T. Maddox
12	Dangle	Cooke	Phillips Petr. Co.	Danglemeyer No. 1
13	Fleitman	Cooke	Benson Bros. et al.	J. H. Cooke No. 1
14	Walnut Bend	Cooke	Sinclair-Prairie	W. E. Winger No. 1
15	Walnut Bend	Cooke	F. Snuggs et al.	McGeorge-Snuggs No. 1
16	Ellis	Jack	Hanlon-Buchanan	Ellis & DuBose No. 1
17	Hoefle	Jack	Hanlon-Buchanan	M. H. Leach No. 1
18	McDonald	Jack	Standard of Texas et al.	J. W. Carter No. 1
19	Peek	Jack	Standard of Texas et al.	R. B. Peek No. 1
20	Pursley	Jack	Shell Oil Co.	W. T. Pursley No. 1
21	Weir	Jack	Continental Oil Co.	W. C. Weir No. 1
22	Wolfe	Jack	Shell Oil Co.	L. N. Wolfe No. 1
23	Denver	Montague	Sinclair-Prairie	C. R. Henderson No. 1
24	Hildreth	Montague	Continental Oil Co.	J. Hildreth No. 1-A
25	Mueller	Montague	Continental Oil Co.	W. Richardson No. 1
26	Airport	Wichita	Consolidated Oil Co.	A. Laukhuff No. 1
27	Davidson	Wichita	Consolidated Oil Co.	A. Davidson No. 1
28	West	Wichita	Continental Oil Co.	G. T. West No. 1
29	Main	Wilbarger	The Texas Co.	E. Main No. 1
30	Rogers-McCrary	Wilbarger	Rogers Bros.	McCrary No. 1
31	Waggoner Ranch	Wilbarger	W. T. Waggoner Est.	Waggoner "MM" No. 1
32	Wilkinson	Wilbarger	British-American	Wilkinson No. 1
33	Barrett	Young	British-American	Carpenter-Barrett No. 1
34	Fish Creek	Young	Keith, Reimer et al.	Wallace Heirs No. 1
35	Morrison	Young	Deep Rock	R. Morrison No. 1
36	Murray	Young	Anderson-Prichard	W. T. Donnell No. 1
37	Murray	Young	Anderson-Prichard	J. Latimer No. 1
38	Murray	Young	Anderson-Prichard	H. C. Meyers No. 1
39	Murray	Young	Standard of Texas, et al.	S. R. Donnell No. 4

TABLE 2.—(*Continued*)

DISCOVERIES, EXTENSIONS, AND IMPORTANT WILDCATS DRILLED DURING 1943

	Survey	Producing Formation	Depth Completed, Ft.	Total Depth	Deepest Horizon Tested	Initial Production Per Day Oil U. S. Bbls.	Choke or Bean, Fractions of an Inch	Remarks
1	L. P. Hunt	Strawn	4,936–4,978	4,983	Strawn	828	¾ choke	New pay
2	I. Holman	Bend	4,468–4,472	5,165	Mississippi	478	¼ choke	One well only
3	H. & T. C.	Bend	5,360–5,375	5,507	Ellenburger	340	Pumping	One well only
4	A. T. N. C. L.	Bend	4,881–4,891	5,623	Bend	377	⅜ choke	Three producers
5	A. T. N. C. L.	Ellenburger	4,937–4,973	4,973	Ellenburger	872	⅜ choke	New pay, extension
6	S. P. R. R.	Strawn	4,329–4,351	4,351	Strawn	95	Pumping	Extension to old field
7	St. Augustine	Mississippi	6,005–6,044	6,044	Mississippi	1,197	¼ choke	Three producers
8	W. Walker	Strawn	4,050–4,060	5,527	Bend?	118	Pumping	New pay
9	G. W. Stipps	Mississippi	6,011–6,049	6,049	Mississippi	390	9/32 choke	Two producers
10	J. Cook	Mississippi	6,153–6,283	6,795	Ellenburger	1,998	2 choke	One prod., no failures
11	T. M. Hughes	Bend	5,475–5,506	5,672	Bend?	25	Pumping	One prod., now shut down
12	Langford	Ellenburger	2,179–2,183	2,183	Ellenburger	818	¾ choke	One prod., no failures
13	A. Patterson	Strawn	1,148–1,170	1,702	Strawn	60	Pumping	Seven producers
14	Fannin C. S. L.	Strawn?	5,495–5,535	5,550	Simpson?	885	2 choke	New pay, 28 producers
15	Fannin C. S. L.	Strawn	4,285–4,300	6,010	Ellenburger	119	Pumping	Extension
16	J. W. Williams	Bend	4,785–4,827	4,828	Bend	515	¼ choke	Ten producers
17	J. S. Porter	Strawn	2,712–2,725	5,953	Ellenburger	65	Pumping	New pay
18	Wm. McDonald	Strawn	3,518–3,538	6,040	Ellenburger	136	⅜ choke	Three producers
19	T. E. & L.	Bend	4,578–4,589	4,589	Bend	245	¼ choke	One well only
20	N. A. Slaughter	Mississippi	5,443–5,634	6,011	Ellenburger	35	Pumping	One well only
21	G. Kaltrider	Strawn	2,328–2,336	6,011	Mississippi	67	Pumping	Two producers
22	T. E. & L.	Bend	4,375–4,405	5,631	Ellenburger	69	2 choke	One well only
23	W. E. Martin	Bend	6,073–6,087	7,766	Ellenburger	81	Pumping	One well only
24	E. T. R. R.	Bend	6,061–6,107	6,109	Bend	1,133, 6 hr.	1 choke	New pay
25	F. Hamilton	Bend	6,015–6,027	6,073	Bend	341	⅝ choke	New pay
26	Cherokee C. S. L.	Strawn	4,415–4,465	5,401	Ellenburger?	104, 4 hr.	¼ choke	Two prod., no failures
27	R. McDowell	Ellenburger	5,353–5,364	5,364	Ellenburger	103, 2 hr.	¾ choke	Two prod., no failures
28	G. W. Scott	Strawn	4,245–4,260	5,687	Ellenburger	185	7/32 choke	Five prod., no failures
29	H. & T. C.	Canyon	2,786–2,796	4,725	Granite Wash	98, 2½ hr.	2 choke	One well only
30	H. & T. C.	Cisco	1,476–1,489	1,489	Cisco	145	Pumping	Five prod., extension to old area
31	H. & T. C.	Ellenburger	4,429–4,490	4,509	Ellenburger	792	⅜ choke	Five prod., no failures
32	Wagg. Col. Sub.	Bend	5,780–5,863	6,133	Ellenburger?	71	Pumping	One well only
33	E. W. Sargent	Mississippi	5,180–5,195	5,530	Ellenburger	293	⅜ choke	One well only
34	M. E. Criswell	Bend	4,104–4,108	4,108	Bend	450, 13 hr.	2 choke	New pay
35	F. McLaurin	Mississippi	4,441–4,457	4,457	Mississippi	263	¼ choke	One well only
36	M. Edmonds	Bend	4,182–4,195	4,768	Ellenburger	132	½ choke	Extension, two prod.
37	Young Co. S. L.	Bend	3,635–3,643	3,643	Bend	65	½ choke	Extension, one prod.
38	G. W. Walsh	Bend	4,254–4,259	4,858	Ellenburger	278, 3 hr.	¾ choke	Extension, one prod.
39	T. E. & L.	Bend	3,745–3,750	4,606	Mississippi	82, 6 hr.	¼ choke	New pay

Number of oil wells completed in 1943 543
Number of gas wells completed in 1943 2
Number of dry holes completed in 1943 588

Oil and Gas Production in North Central Texas in 1943

By V. C. Perini, Jr.,* Member A.I.M.E.

The North Central Texas district as herein defined includes the counties of Brown, Callahan, Coleman, Comanche, Coryell, Eastland, Erath, Fisher, Hamilton, Haskell, Hood, Jones, Lampasas, Mills, Nolan, Palo Pinto, Parker, San Saba, Shackelford, Stephens, Stonewall, Summerville, Taylor, Throckmorton and Wise. These counties as listed are the counties of District 7B, State Railroad Commission. In the new designation of districts for the Transactions, the North Central Texas district includes most, but not all, of the counties of the previously classified West Central Texas district. This district covers the south central crest and the west flank of the Bend flexure north of the Llano uplift. The west flank of the Bend flexure is on the east boundary of the Permian Basin of West Texas.

The greater part of the oil and gas produced in this district has been from Pennsylvanian strata. Some oil and gas has been produced from the lower Permian (by the latest selection of the Pennsylvanian-Permian boundary) and minor amounts from the Mississippian and Ordovician sediments. Increasingly important quantities of oil and gas are to be expected from the older sediments by deeper development in proven fields and by new discoveries. Most of the oil and gas in the district has accumulated in localized, well-defined structural traps in limestone and sandstone reservoirs and in traps due to stratigraphic changes in sedimentation, mainly porosity traps in limestone and sandstone lenses, both usually associated with some structural feature. These features are found by surface and subsurface geological structural mapping, by core drilling and by geophysical surveying. Geochemical methods are also the basis for some wildcatting.

The demand for sweet crude oil from this district is firm for local and national consumption, but the market price for the oil remains practically the same as in 1941. The price is not adequate to meet the requirements of the average independent operator with the continued advance in production, development and wildcatting costs. Stripper wells are being plugged daily and should be jealously saved for the future local and national reserves, especially in view of the fact that new discoveries of commercially important oil and gas reserves are not keeping pace with consumption. An expected economic disruption attendant upon the national war effort has arisen and continues in the future outlook for this district. The lack and delay of securing replacement parts for almost all oil-field equipment has handicapped and delayed operations and has decreased efficiency in wildcatting, development and production. Sufficient experienced drilling, scientific and office personnel is lacking because of inductions in the armed forces and migration to war industries during the period before manpower conservation became effective. The office personnel of the average oil and gas producer continues to be swamped by the increasing demands for reports by state and federal bureaus. An average of 10 days

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of each month is required for these compilations. Duplications are very evident, which should be remedied by combining many forms to serve more than one state and federal bureau and other forms should be simplified.

The average pool in the North Central Texas district was not adaptable to the original Federal 40-acre spacing regulation. The new Federal order issued in May 1943, allowing 5, 10 and 20-acre spacing patterns, depending on depth, was timely and caused an increase in the development of known pools and a decrease of dry holes in the proven areas.

GEOLOGY

Geological debate continues as to the proper designation of the Permian-Pennsylvanian boundary in the western area of this district. Also in the debate is the correlation of the productive sandstone and limestone reservoirs within the several counties. This is due to complications arising from lateral variations in sedimentation, the lack of system in naming the numerous producing reservoirs and correlating with the established individual members of formations. Most of the productive pays are given the name of the owner of the land on which the discovery well was drilled or the name of the company that drilled the well. These names, by local usage, are given eventually to the individual members of the formations without any attempt of clarification by use of established nomenclature. As a result, some producing zones and formation members have several names. The formation and reservoir names used herein are the names adopted by local usage, and no attempt has been made to clarify the nomenclature by correlation with established members of formations. The basal Permian (Wolfcamp) and upper Pennsylvanian (Cisco) have numerous minor disconformities or diastems, channels and probably a major disconformity between the two series, which add to the perplexity of the problems. M. G. Cheney,[1] in his geological studies of North Central Texas based on paleontological and lithological determinations, defines the Permian-Pennsylvanian boundary as 40 to 150 ft. below the Saddle Creek limestone. In subsurface the position of the Saddle Creek limestone has been established in most of this area and is used extensively in correlation determinations as an important datum. For the purpose of this report and subject to change by additional study, the Permian-Pennsylvanian boundary is placed at the contact, usually a weathered zone, at the top of the Flippen limestone with the base of the clastic zone below the Saddle Creek limestone. In this clastic zone are the productive Bluff Creek and Flippen sandstones.

PRODUCTION OF GAS

This district has been and is one of the important gas-producing districts in the state and an earnest attempt was made to compile cumulative gas-production figures for most of the fields for publication, but the limited time available for preparing the report and the lack of cumulative records for the gas produced made the task almost impossible. Only the gas purchased from a few of the fields by the Lone Star Gas Co. and the Community Natural Gas Co. is listed in Table 1. This is a minor amount of the gas that has been produced in the past and is being produced at the present time. There are numerous gasoline plants, recycling and repressuring plants, which are not listed.

DRILLING AND DISCOVERIES

The total oil production during 1943 was slightly more than in 1942 (8,964,888 bbl. in 1942, 8,966,243 bbl. in 1943). The Railroad Commission production schedule

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[1] M. G. Cheney: *Bull.* Amer. Assn. Petr. Geol. (1940) **24**, 1.

TABLE 1.—*Oil and Gas Production in North Central Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil Wells[f]
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943
	BROWN COUNTY							
1	Brownwood, East*	1919	1,600			2,184.7	271.4	
2	West*	1927	1,800			2,118.9	607.7	
3	Byler	1926	300	868,462	4,430			20
4	Byrd Store	1920	400	406,890	2,012			7
5	Childress	1927	300	926,818	20,964			59
6	Clark-Buffalo	1927	460	826,886	14,604			28
7	Cross Cut Area	1921	2,300	6,552,180	60,914			132
8	Fry	1925	940	8,081,456	70,291			83
9	George	1927	200	941,815	35,389			31
10	Jannellan*	1918	1,600			7,323.8	734.4	
11	Salt Creek*	1928	1,500			180.8	180.8	
12	Smith Ellis	1926	450	2,464,881	39,527			36
13	Stover	1926	1,500	7,764,519	114,238			155
14	Others	1917	5,800	2,892,307	59,971			253
15	Total Brown County		19,150	31,726,214	422,340			804
	CALLAHAN COUNTY							
16	Baum	1925	500	945,442	7,897			18
17	Hatchett	1927	375	1,505,519	25,464			80
18	Isenhour	1923	600	2,297,683	8,627			119
19	Moutray	1926	400	2,726,667	43,060			89
20	Scranton	1939	160	101,467	16,112			8
21	Others	1920	9,620	7,898,928	141,089			810
22	Total Callahan County		11,655	15,475,706	242,249			1,124
	COLEMAN COUNTY							
23	Anzac, Morris	1937	200	253,094	50,353			14
24	Burkett, Shallow	1924	850	2,596,564	60,666			173
25	Burkett, Deep	1930	160	728,957	6,816			17
26	Coker	1942	400	162,370	108,641			13
27	Dibrell, Gayle	1926	320	565,794	29,415			17
28	Eastland	1927	270	2,161,914	25,339			22
29	Goldsboro	1927	260	1,080,334	46,193	2,912 6	225.2	10
30	Jennings	1926	160	520,578	10,798			25
31	Jim Ned (Jim Ned*)	1941	200	27,178	11,156	469.7	288.5	2
32	Morris*	1925	1,000			450.2	854.0	3
33	Novice	1927	1,050	1,074,273	188,164			48
34	Overall	1927	340	1,450,632	35,589	523.5	91.7	7
35	Santa Anna (Santa Anna*)	1915	240	487,452	10,736	3,585.3	1,325.1	10
36	Silver Valley	1941	640	210,977	91,616			13
37	Stewardson	1929	240	469,010	11,825			14
38	Valera*	1918	1,500			1,315.4	103.8	
39	Others	1910	1,000	1,208,067	26,486			16
40	Total Coleman County		8,830	12,997,194	713,793			404
	COMANCHE COUNTY							
41	Amity	1939		297,573	67,230			61
42	Sipe Springs*	1919	1,500			6,452.6	564.7	
43	Sipe Springs	1919	800	714,028	14,028			
44	Others			981,458	10,211	668.0	31.3	
45	Total Comanche County		2,300	1,903,059	91,469			112
	COMANCHE, EASTLAND, ERATH COUNTIES							
46	Desdemona	1918	6,020	23,771,044	127,202			58

* See page 271 regarding listing of gas production.

[b] Footnotes to column heads and explanation of symbols are given on page 270.

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Character of Oil[i]	Producing Formation				
	Oil		Gas	Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Depth Top Prod. Zone	Av. Ft. Bottoms Prod. Wells	Structure[o]
	Flowing	Artificial Lift							
					BROWN COUNTY				
1			13		Big Saline, Pen	L		1,700	A
2			30		Big Saline, Pen	L		15–1,700	A
3				39	Fry, Pen	S		1,300	AL
4				37	Big Saline (Bend), Pen	L		2,450	A
5				35	Childress, Pen	S		800	AL
6				42	Fry, Pen	S		1,150	NL
7				40	Cross Cut, Pen	S		1,200	NL
8				42	Fry, Pen	S		1,300	NL
9				39	Fry, Pen	S		1,300	NL
10			24		Caddo, Pen	L		1,100	A
11			6		Big Saline, Pen	L			A
12				41	Fry, Pen	S		1,300	NL
13				41	Blake, Pen	S		1,200	NL
14			5		Pen	S-L	100	3,000	
15	3	811	78						
					CALLAHAN COUNTY				
16				39	Cross Plains, Pen	S		1,780	NL
17				38	Moutray, Per	S		400	NL
18				37	Isenhour, Per-Pen	S		700	NL
19				37	Moutray, Per	S		750	DL
20			6		Cathey, Pen	S		1,675	NL
21					Moran to Ellenburger, Per-Ord	S-L	150	4,300	
22	9	1,115	6						
					COLEMAN COUNTY				
23				44	Morris-Cross Cut, Pen	S		2,100	NL
24				34	Burkett, Pen	S		400	NL
25				41	Cross Cut, Pen	S		1,550	NL
26	13	0		42	Morris, Pen	S		3,060	NL
27				42	Morris, Basal Big Saline, Pen	S-Cong	1,900	3,200	NL
28				42	Up Fry, Pen	S		2,000	NL
29	7	3		42	Gardner-Gray, Pen	S	3,850	3,975	TL
30				32	Jennings, Pen	S		1,200	NL
31	2	0	4	42	Morris-Gray, Pen	S	3,400	3,900	TL
32			3		Morris, Pen	S		2,200	A
33	48	0		41	Gardner, Pen	S		3,600	TL
34				42	Cisco Canyon-Strawn (5),[1] Pen	S		2,100	DL
35			38	39	Fry-Big Saline (gas), Pen	S	1,500	2,200	NL
36	13	0		43	Gray, Pen	S		3,600	NL
37				40	Fry-Gardner, Pen	S		1,450	NL
38			2		Gray, Pen	S		3,100	NL
39			1		Pueblo-Ellenburger, Per-Ord	S-L	400	3,850	
40	98	306	48						
					COMANCHE COUNTY				
41				38	Blake, Pen	S		600	NL
42			25		Big Saline, Pen	L		2,700	A
43				39	Sipe Springs, Pen	S		350	NL
44			8		Strawn-Bend-Ellenburger, Pen-Ord	S-L	300	4,000	
45	6	106	33						
					COMANCHE, EASTLAND, ERATH COUNTIES				
46				40	Desdemona (Big Saline), Pen	S		2,750	DL

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[1] Figures in parentheses indicate number of productive reservoirs.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil Wells[f]
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943
	EASTLAND COUNTY							
47	Carbon	1939	200	83,331	7,624			7
48	Cisco*					1,675.4	94.9	
49	Eastland*	1923	80			3,251.7	2.2	
50	Hilburn	1919	420	1,147,899	9,049			5
51	Leeray*	1927				31,547.9	2,986.3	
52	Mangum	1922	300	1,051,081	31,464			49
53	Pioneer	1919	1,400	5,707,509	45,896			53
54	Ransour	1926	250	1,585,477	25,025			8
55	Thorpe*	1936	160			67.5	67.5	
56	Others	1917	28,000	66,915,481	525,533			289
57	Total Eastland County		30,810	76,490,778	644,591			411
	ERATH COUNTY							
58	X-Ray*	1920	5,600			13,974.0	788.7	
59	Others*							
60	Total Erath County							
	FISHER COUNTY							
61	Howard	1934	180	211,887	8,215			3
62	McCaulley	1941	200	112,570	48,581			6
63	Rotan	1936	640	1,410,207	86,405			27
64	Rotan, West	1937	80	73,512	6,161			2
65	Royston	1928	2,900	12,055,310	331,070			97
66	Total Fisher County		4,000	13,863,486	480,432			135
	HAMILTON COUNTY							
67	Pottsville*	1936	800			562.1	345.4	
	HASKELL COUNTY							
68	Lawson	1942	80	5,774	2,457			2
69	Moody	1928	80	127,018	2,965			6
70	Pardue	1938	80	74,723	4,125			3
71	Others		10	12,072	1,000			1
72	Total Haskell County		250	219,587	10,547			12
	JONES COUNTY							
73	Akard	1938	500	397,279	134,006			30
74	Appling	1939	80	71,043	5,243			2
75	Avoca	1935	740	2,570,397	469,313			50
76	Avoca, Griffen	1936	640	2,649,659	512,628			64
77	Avoca, North	1938	260	191,147	80,365			6
78	Avoca, West	1941	80	37,974	19,081			3
79	Dorsey, Hawley	1933	600	3,355,195	94,463			65
80	Guitar, Hawley	1936	400	847,016	23,195			37
81	Hardy	1943	40	1,741	1,741			1
82	Jennings, Lueders	1934	160	602,029	8,927			13
83	Lewis, Steffens	1936	1,500	2,656,010	163,779			162
84	Noodle Creek	1927	1,030	7,295,773	126,194			67
85	Noodle Creek, Irvin	1937	500	493,011	90,335			21
86	Noodle Creek, South	1941	360	154,275	85,673			14
87	Noodle Creek, Central	1943	200	26,876	26,876			4
88	Sandy Ridge-Higgs	1926	500	435,467	40,065			28
89	Sayles	1932	900	2,642,822	266,802			79
90	Stith	1940	160	45,809	19,951			6
91	Strand	1941	400	70,433	45,899			5
92	Triplett	1940	160	77,239	10,217			3
93	Wimberly	1941	1,250	627,992	418,243			61-24 D
94	Others	1926	340	410,307	39,414			18
95	Total Jones County		10,800	25,659,494	2,682,410			739-24D

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Character of Oil[i]	Producing Formation				
	Oil		Gas	Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Depth Top Prod. Zone	Av. Ft. Bottoms Prod. Wells	Structure[o]
	Flowing	Artificial Lift							
EASTLAND COUNTY									
47				40	Caddo Pool Blk L, Pen	L		2,600	NC
48			23						
49			6		Lake, Pen	S		3,000	
50				31	Big Saline, Pen	L		3,100	A
51			50		Strawn-Big Saline, Pen	S	1,950	3,800	
52				38	Strawn, Pen	S		1,200	NL
53				41	Pioneer (Parks), Pen	L		2,450	AF
54				38	Big Saline, Pen	S		3,600	N
55					Strawn, Pen	S		1,700	
56			30						
57	30	381	109						
ERATH COUNTY									
58			34		Big Saline (Ranger), Pen	S-L		3,225	A
59			3						
60			37						
FISHER COUNTY									
61				38	Upper Hope, Pen	L		3,670	AD
62				42	Camp Colorado-Up. Hope, Per-Pen	L		3,330	NC-AC
63				38	Camp Colorado, Per	L		3,500	NC
64				39	Camp Colorado, Per	L		3,600	NC
65				39	Royston (Flippen), Pen	L		3,100	A
66	0	135							
HAMILTON COUNTY									
67			5		Big Saline (Marble Falls), Pen	L	2,600	2,800	A
HASKELL COUNTY									
68	1	1		40	Canyon (Reef), Pen	L		2,685	D
69				38	Hope, Pen	S		1,800	NL
70				39	Upper Canyon, Pen	L		2,850	A
71									
72	2	10							
JONES COUNTY									
73	17	13		39	Flippen, Per	S		2,150	AL
74	0	2		36	King-Swastika, Pen	S		2,640	NL
75	42	8		42	Palo Pinto, Pen	L		3,260	A
76	44	20		42	Palo Pinto, Pen	L		3,240	A
77	6	0		42	Palo Pinto, Pen	L		3,240	A
78	0	3		42	Palo Pinto, Pen	L		3,245	A
79	0	65		39	L Per U Cisco (8), Per-Pen	S-L	1,900	2,300	DL
80				37	Flippen S-L-Up. Hope, Pen	S-L		2,000	AL
81	1	0		40	Canyon, Pen	S	3,690	3,715	NL
82				39	King, Pen	S		2,040	A
83	2	182		38	Bluff Creek, Per	S		1,900	NL
84				38	Camp Colorado, Per	L		2,500	AC
85				39	Camp Colorado-Up. Cisco, Per-Pen	L-S	2,350	3,000	AL
86	4	10		44	Camp Colo.-Swastika, Per-Pen	L-S	2,726	2,950	AC
87	1	3		39	L. Hope-Swastika, Pen	L-S	2,735	3,000	A
88				37	Bluff Creek, Per	S		1,900	NL
89	22	57		41	Flippen, Per	S		1,950	TNL
90	4	2		42	Flippen-Hope-Gunsight, Per-Pen	S-L	2,350	2,670	AL
91	3	2		36–41	Palo Pinto, Pen	L		3,400	A
92	0	3		36–42	Flippen S-L Hope, Pen	S-L	2,190	2,700	AL
93	55-24D	6		38–45	L. Per-U. Cisco (7), Pen	S-L	2,100	2,600	AL
94		0							
95	206-24D	533							

Table 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil Wells[f]
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943
	Palo Pinto County							
96	Boles*	1943?	160			1,509.2	0.0	
97	Brad*	1922	320			3,361.3	0.1	
98	Gordon*	1932	400			739.0	6.6	
99	Lone Camp*	1929	500			896.3	44.1	
100	Marston Spur*	1922				479.0	71.0	
101	Nolan*	1941	160			95.4	54.5	
102	Rector*					1,498.9	136.5	
103	Ringo					199.3	64.8	
104	Strawn (Strawn*)	1915	1,200	3,088,124	41,873	28,764.8	1,212.8	100
105	Others		1,500	2,170,222	47,993			30
106	Total Palo Pinto County		4,240	5,258,346	89,866			130
	Shackelford County							
107	Bluff Creek	1930	1,100	4,559,999	239,723			274
108	Cook Ranch	1925	1,620	18,266,293	512,559			393
109	Frye	1925	120	357,379	6,084			59
110	Hope	1923	220	1,542,322	50,809			57
111	Ibex	1921	1,240	2,499,724	15,349	58,614.1	1,079.0	20
112	Ivy	1937	900	2,252,759	356,078			77
113	Nail	1927	540	05,334	138,936			48
114	Newell	1924	700	993,755	40,383			85
115	Simmons-Harvey	1925	160	475,818	18,357			20
116	Tannehill-Mathews	1927	300	2,633,782	74,881			62
117	Others	1911	6,580	11,666,735	336,391			911
118	Total Shackelford County		13,480	45,953,900	1,789,550			2,006
	Stephens County							
119	Caddo, North*	1938				391.5	318.7	
120	Caddo, South*	1928				264.8	41.0	
121	Curry	1921	2,600	9,944,659	93,490			51
122	Frankel*					1,258.5	41.1	
123	Hohertz, Strawn	1915	850	4,843,045	56,948			84
124	La Casa*					3,962.6	119.9	
125	Loving (Eolian)	1939	360	191,724	49,738			16
126	Stribling	1939	320	196,075	16,128			9
127	Wiles*	1930	400			353.2	27.6	
128	Others	1916	45,910	116,063,600	947,126			453
129	Total Stephens County		50,440	131,239,103	1,163,430			613
	Stonewall County							
130	Aspermount	1940	80	40,533	8,078			2
131	Boyd	1939	40	35,051	5,511			2
132	Carlisle	1938	100	124,142	21,942			2
133	Total Stonewall County		220	199,726	35,531			6
	Taylor County							
134	Bowles	1937	120	110,119	2,329			2
135	Merkel	1941	280	132,386	72,260			13
136	Reddin	1942	125	129,453	115,901			5-3 D
137	South View	1940	240	201,927	43,130	649.3		11
138	Trent	1942	80	14,583	3,658			2
139	Others	1929	340	472,885	39,196			19
140	Total Taylor County		1,185	1,061,353	276,474			52-3 D

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Character of Oil[i]	Producing Formation				
	Oil		Gas	Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Depth Top Prod. Zone	Av. Ft. Bottoms Prod. Wells	Structure[o]
	Flowing	Artificial Lift							
					PALO PINTO COUNTY				
96			2		Ranger, Pen	S		3,360	
97			2		Big Saline, Pen	S		3,750	A
98			3		Big Saline, Pen	S		3,100	NL
99			1		Big Saline, Pen	S		3,550	NL
100			2		Big Saline, Pen	S		3,200	N
101			1		Big Saline, Pen	S		3,465	
102			4						
103			2						
104			31		Strawn-Big Saline, Pen	S-L		3,000	NL
105			15						
106	4	126	63						
					SHACKELFORD COUNTY				
107			2	37	Bluff Creek, Per	S		1,600	TL
108				37	Cook, Pen	S		1,200	TL
109				35	Frye, Per	S		450	NL
110				37	Hope, Pen	S		1,500	NL
111			17	39	Ibex, Pen	L		3,500	A
112	25	52		39	Cook, King, Palo Pinto, Pen	S-L	1,700	3,200	A
113	0	25		40	Bluff Creek-Cook, Per-Pen	S		1,400	NL
114				37	Tannehill, Per	S		1,100	NL
115				39	Bluff Creek, Per	S		1,700	NL
116				38	Tannehill, Per	S		1,150	NL
117			12		Wolfcamp-Ellenburger, Per-Ord	S-L	200	4,600	
118	31	1,975	31						
					STEPHENS COUNTY				
119			4		Big Saline, Pen	L		4,000	
120					Strawn, Pen	S		2,200	A
121				38	Up. Parks fm., Pen	L		3,100	A
122			2				2,118	3,514	
123			12	39	Strawn, Pen	S		1,850	MLN
124			5						
125	11	5	4	43	Up. Parks fm., Pen	L		3,500	A
126	0	9		42	Up. Parks fm., Pen	L		3,600	A
127			1		Big Saline, Pen	L		3,640	
128			61		Strawn-Bend-Mis Ell, Pen-Ord	L-S	1,900	4,500	
129	32	581	89						
					STONEWALL COUNTY				
130	0	2		40	Strawn-Mis, Pen-Mis	L-S	4,150	6,060	A
131	0	2		39	Palo Pinto, Pen	L		4,725	A
132	0	2		41	Palo Pinto, Pen	L		5,175	AL
133	0	6							
					TAYLOR COUNTY				
134	0	2		38	Cook, Pen	S		1,750	NL
135	0	13		38	Dothan, L. Hope, Per-Pen	L	2,020	2,625	D
136	4-3 D	1		40	Wolfcamp-Up. Cisco (4), Per-Pen	L	2,250	2,500	D
137	5	6	7	36	Flippen, Pen	L		2,400	D
138	0	2		42	Saddle Creek, Pen	S		2,770	N
139	3	16			Wolfcamp-Cisco, Per-Pen		1,600	3,000	
140	12-3D	40							

allowed 226 producing days in 1942 and 249 in 1943.

The total number of wells drilled during 1943 was slightly greater than in the previous year with an increase in the number of wildcats drilled during the latter part of the year. Table 3, as prepared by the Railroad Commission of Texas, shows the comparison of the two years. It should be used with reservations, as there still remains a wide difference of opinion as to the definition of a wildcat, a semiwildcat and an extension to a proven field. Also, it should be noted that in the shallow areas of this district, where oil is found at depths from 300 to 1500 ft. in lenticular sandstones and variable porosities in limestone, many of the wells listed as dry oil and gas wells in proven fields should be considered as wildcats. Some other wildcat oil and gas discoveries are not credited in this table, because of incomplete records in the Railroad Commission files at the end of the year.

During the year this district is credited with 10 wildcat oil discoveries, 5 wildcat gas discoveries, 5 extensions of proven fields and 9 new productive reservoirs in old fields. Not many may be considered at this time as of major importance as large reserves, but future development by extensions and deeper drilling may increase the productivity of the areas. By counties, the following are considered important:

Coleman County

The Anzac Oil Corporation No. 1 Hinds, sec. 700, J. H. Barkley survey, is a ½ mile east extension of the Overall field producing in the upper Fry sandstone, a member of the Strawn formation of Pennsylvanian age. The well pumped 142 bbl. of 42° gravity oil on potential test at a depth of approximately 2000 ft., and is on the northeast-southwest structural axis of the field as shown by surface and subsurface structural geology. Development is in progress to define the limits of this area.

The Sohio Oil Co. and Hunter & Hunter Williams No. 1, sec. 18, T. and N. O. R. R. Co. survey, block 2, is a wildcat oil and gas discovery credited to core drilling and subsurface structural interpretation. The well produced 15 bbl. of 40° gravity oil and 1200 M cu. ft. of gas from the Gray sandstone, a member of the Strawn formation of Pennsylvanian age, at a depth of 3723 to 63 ft. An analysis of the 40 ft. of sandstone drilled indicates the upper

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil Wells[f]
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943
	THROCKMORTON COUNTY							
141	McKnight	1941	160	45,387	17,370			2
142	Parrott	1941	80	18,746	9,412			2
143	Woodson, Deep	1929	320	1,980,395	38,350			11
144	Woodson, Shallow	1926	200	808,362	13,265			6
145	Others	1924	1,000	1,201,631	117,122			230
146	Total Throckmorton County		1,760	4,054,521	195,519			251
	WISE COUNTY							
147	Park Springs	1942	40	1,463	840			1

25 ft. as gas sandstone and the lower 15 ft. as oil sandstone. On completion, the casing was cemented through the gas sand. The operators are now drilling the second well 990 ft. west and 330 ft. north of the discovery well to test the sandstone below the gas cap at a lower structural position. Future drilling will ascertain the value of this area as a new oil and gas reserve. The new discovery is 1½ miles south of the West Novice field, which produces from the Gardner sandstone at about 3600 feet.

Jones County

The R. H. Roark No. 1 Sears, a wildcat oil discovery, sec. 37, T. and P. Ry. Co. survey, block 18, between the South Noodle and the Irvin Noodle fields, is on a separate structural feature and the discovery is credited to core drilling based on structural information on the Bull Wagon dolomite of the Clear Fork formation, Permian age. The discovery well is producing from the "Lower Hope," a Pennsylvanian limestone reservoir, at 2735 to 2738 ft. The well on potential test flowed 253 bbl. of 39° gravity oil through 2-in. tubing in 24 hr. Since the discovery, other wells have been deepened to the "Swastika" Pennsylvanian sandstone at a depth of 3000 ft. The first well drilled to this sandstone produced 60 bbl. of 44.5° gravity oil in 24 hr. by flowing through 2-in. tubing. Four wells were completed at the end of the year, increasing the productive acreage in the Noodle Creek area 200 acres.

The Cardinal Oil Company's No. 1 Carter, sec. 33, T. and P. Ry. Co. survey, block 18, a new productive reservoir discovery in the South Noodle Creek field encountered a shallower reservoir at 2446 to 2448 ft. The well pumped 274 bbl. of 40° gravity oil in 24 hr. This reservoir is in the basal part of the Camp Colorado limestone of Permian (Wolfcamp) age, and it is the same productive limestone (Noodle Creek) that produces on the west flank of the original Noodle Creek pool. Eight wells were completed in this new reservoir at the end of the year, increasing the productive area 200 acres.

The Great Lakes Carbon No. 1 Hardy, sec. 11, T. and P. Ry. Co. survey, block 4, is a wildcat oil discovery and is producing from a Canyon sandstone of Pennsylvanian age at the depth of 3690 to 3715 ft. The well flowed 154 bbl. of 40° gravity oil through a ¼-in. choke in 24 hr., tubing pressure 75 lb., gas-oil ratio 250:1. This sandstone reservoir is new in this district

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Character of Oil[i]	Producing Formation				
	Oil		Gas	Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Depth Top Prod. Zone	Av. Ft. Bottoms Prod. Wells	Structure[o]
	Flowing	Artificial Lift							
THROCKMORTON COUNTY									
141	1	1		40	Parks, Pen	L		4,050	A
142	1	1		40	Parks, Pen	L		4,020	A
143			1	38	Parks, Pen	L		3,900	A
144				37	Canyon-Strawn (3), Pen	S	1,750	3,150	A
145					Cisco to Chappel, Pen-Mis	S-L	300	4,500	
146	4	247							
WISE COUNTY									
147	1			39	Big Saline, Pen	S		5,818	

and correlates with the Canyon producing sandstones above the Palo Pinto limestone in the North Texas district. The well was completed after being plugged back from a total depth of 4812 ft., at which depth the well penetrated the Upper Strawn formation of Pennsylvanian age. The Palo Pinto limestone, the Avoca field productive reservoir, was not encountered in the well as the limestone apparently is replaced by dark calcareous shale. The discovery of this pool is credited to geochemical methods, making the second success and the sixth failure for this method in this district. The new pool has been defined on the east and southeast by two dry holes due to the absence of the producing sandstone. It has been limited to the northwest by a structurally low dry hole, which encountered 75 ft. of the producing sandstone carrying salt water. Subsurface control to date suggests that the accumulation of the oil is due to a sandstone lens trap associated with a plunging anticlinal nose combined with a structural terracing. Further drilling will ascertain the eco-

TABLE 2.—*Summary of Drilling Operations in North Central Texas*

Important Wildcats Drilled in 1943

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Blk.	Survey			
1	Coleman	687		J. P. McLean	3,162	Per	Strawn Pen
2	Coleman	18	2	T. & N. O.	3,763	Cre	Strawn Pen
3	Coleman	700		J. H. Barkley	2,098	Per	Strawn Pen
4	Eastland	66	4	H. & T.C.	3,448	Pen	Big Saline ? Pen
5	Eastland	67	4	H. & T.C.	3,600	Pen	Big Saline ? Pen
6	Fisher	180	2	H. & T.C.	3,626	Per	Cisco Pen
7	Fisher	51	1	H. & T.C.	3,302	Per	Cisco Pen
8	Jones	37	18	T. & P.	2,735	Per	Cisco Pen
9	Jones	40	18	T. & P.	3,000	Per	Cisco Pen
10	Jones	33	18	T. & P.	2,448	Per	Wolfcamp Per
11	Jones	11	4	H. & T.C.	4,812 P.B.	Per	Strawn Pen
12	Jones	20	17	T. & P.	2,200	Per	Wolfcamp Per
13	Jones	3		J. W. McKissick	2,535	Per	Cisco Pen
14	Palo Pinto	59	2	T. & P.	3,973	Pen	
15	Palo Pinto			M. E. Conaster	1,471	Pen	
16	Palo Pinto	52	2	T. & P.	3,949	Pen	
17	Shackelford	139		E.T.R.R.	1,611	Per	Cisco Pen
18	Shackelford	166		E.T.R.R.	1,501	Per	Cisco Pen
19	Stephens	1,092		T.E. & L.	4,250 P.B.	Pen	Big Saline Pen ?
20	Stephens	1,122		T.E. & L.	4,230	Pen	Chappel Miss
21	Stephens	114		T.E. & L.	4,170	Pen	Chappel Miss
22	Stephens			J. C. Garrett	4,372 P.B.	Pen	Chappel Miss
23	Stephens	46	7	T. & P.	1,859	Pen	Strawn Pen
24	Stephens	1,144		T.E. & L.	4,601 P.B.	Pen	Ellenburger-Ord
25	Stephens	69	4	T. & P.	1,981	Pen	Strawn Pen
26	Stephens	2	1	S.P.R.R.	4,150 P.B.	Pen	Big Saline Pen
27	Stephens	456		S.P.R.R.	3,610	Pen	Big Saline Pen ?
28	Taylor		9	J. F. Nabors	2,632	Per	Cisco Pen
29	Taylor		9	J. F. Nabors	2,650	Per	Cisco Pen
30	Throckmorton	1,691		T. E. & L.	4,311 P.B.	Pen ?	L. Pen ?

nomic importance of this new field as an oil reserve.

Wimberly Field, Jones County, and Reddin Field, Taylor County

The development and dual completions of the deeper Pennsylvanian reservoirs in the Wimberly field, Jones County, and the Reddin field, Taylor County, have added considerably to the oil reserves of these fields and this district. The reserve estimates as yet are not available. The two wells dually completed this year in the Reddin field have proved about 100 acres.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1943

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Ellis & Estes	18 P					Discovery, Pen Gardner S 3134 to 3140
2	Sohio, Hunter & Hunter	15 F	1.20	2	1,150	1,150	Discovery, Pen Gray S 3723 to 3763
3	Anzac Oil Corporation	142 P					Extension, Overall Pen U Fry S 2000
4	Hickok Prod. & Div. Co.		2.80		1,250		Extension, Ward Pen Lake S 3448
5	Hickok Prod. & Div. Co.		2.00		1,280		New prod. reservoir Ward Pen Big Saline L 3600
6	Northern Ordnance, Inc.	30 P					Extension, Howard Pen Up Hope L 3721 to 3726
7	Stephenson, et al	(2 hr.) 225 F		2			New prod. reservoir, McCauley Pen Up Hope L 3301 to 3302
8	R. H. Roark	253 F		¾			Discovery, Noodle, Central Pen L Hope 2735 to 2738
9	R. H. Roark	60 F		2	200		New prod. reservoir, Noodle, Central Pen Swastikas 2998
10	Cardinal Oil Company	274 P					New prod. reservoir, Noodle, South, Per Camp Colo L 2446 to 2448
11	Great Lakes Carbon Co.	154 F		¼	700	75	Discovery, Hardy Pen Canyon S 3690–3715
12	Fain & McGaha	73 P					Discovery, Patterson Per Tannehill S 2200 to 2205
13	Alder, Merry Bros. & Perini	25 P					Discovery, Hawthorne Pen Up Hope L 2535 to 2538
14	W. K. Gordon		0.83		1,395		Discovery, Pen Ranger S 3969 to 3973
15	Hickok & Reynolds		2.70		500		Extension, Pen Strawn S 1451 to 1468
16	Palo Pinto Oil & Gas Co.		0.80		1,480		Discovery, Pen Ranger S 3949
17	Roeser & Pendleton	91 P					Discovery, Pen Cook S 1605 to 1611 ?
18	Kleiner, et al		1.80				Discovery, Pen Tannehill S 1490–1501
19	Ben F. Reed	800 F		2	200	100	Discovery, Corbett Pen Big Saline S 3950
20	T. P. Coal & Oil Co.	(3 hr.) 503 F		1½	650	550	New prod. reservoir, Eliasville, East Miss Chappel L 4224 to 4230
21	T. P. Coal & Oil Co.	(3 hr.) 165 F		2	675	30	New prod. reservoir, Eliasville, West Miss Chappel L 4160 to 4170
22	T. P. Coal & Oil Co.		7.90				New prod. reservoir, Eliasville, West Pen Big Saline S 3980
23	Cherry, Barren, Kidd		5.80		660		Discovery, Pen Strawn S 1841 to 1856
24	J. D. Hancock	22 F			200	60	Discovery, Pen Caddo L 3251 to 3271
25	T. P. Coal & Oil Co.		4.00		700		Discovery, Pen Strawn S
26	Carey & Carey		11.40		1,650	1,450	Extension, Whalen Pen Big Saline S 4077-4080
27	Woodley Petr. Co.		15.00		1,525		New prod. reservoir, Leeray Pen Big Saline L 3601–3610
28	West Central Drill. Co.	See text					New prod. reservoir, Reddin Pen Gunsight L 2532
29	West Central Drill. Co.	(1 hr.) 15.2 F		¾		150	New prod. reservoir, Reddin Pen Gunsight L 2536
30	Anderson-Prichard	72 P					Discovery, Pen Caddo L 3925–3929

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1943	44	25
Number of oil wells completed during 1943	112	10
Number of gas wells completed during 1943	16	5
Number of dry holes completed during 1943	134	129

The 24 wells dually completed this year in the Wimberly field have proved about 1000 acres. The "Lower Hope" limestone at an average depth of 2300 to 2350 ft. and the "Gunsight" limestone at an average depth of 2400 to 2600 ft. are the two reservoirs usually dually completed. As estimated from electric logs and perforations made in casing, the porosity thickness of the "Lower Hope" averages 28 ft. and the "Gunsight" 38 ft. On test through a ¾-in. choke with 180 lb. flowing pressure, the "Lower Hope" wells average 50 bbl. of 44° gravity oil per hour and the "Gunsight" wells average 65 bbl. of 45° gravity oil per hour. The gas-oil ratio of both pays averages 300:1.

TABLE 3.—*Drilling, Completion and Plugging Summary, North Central Texas**

	1942	1943
Regular drilling applications	490	507
Rule 37 applications:		
Granted	28	20
Denied	0	0
Oil-well completions	188	163
Gas-well completions	17	18
Dry holes	179	247
Wildcats drilled:		
Oil	17	7
Gas	5	2
Dry	95	135
Wells plugged:		
Dry	155	213
Gas	24	13
Oil	152	106

* Railroad Commission of Texas, Oil and Gas Division.

This multizone production method and the unitization agreement among the operators for the development procedure in the Wimberly and Reddin fields is an outstanding example of conservation of material and manpower while increasing the production of oil from the pools. The method is not new but is appropriate to the war effort. The leases were not unitized but, owing to the lack of drilling equipment, special tools and experienced men, the operators, through the able efforts of Edgar Davis, Manager and Production Supt., West Central Drilling Co., agreed on a development plan for using the same drilling equipment and supervisory personnel on all wells deepened to the lower reservoirs and dually completed. The wells to be deepened were placed in such order as to eliminate any unfair drainage across property lines and the wells were so located on different leases as to give the operators their share of the allowables from the deeper reservoirs. The allowable is 60 bbl. per day for each well dually completed.

A flat supervisory fee is charged for each well and one set of special tools, the only set in the two fields, is used for operating the special choke valves. The wells are deepened or drilled to the lowest producing reservoir, then, after electric log and sample determinations are made, casing or a liner is lowered and cemented. The casing is then perforated at the different producing zones. Tubing is run with a hook wall head packer to separate the two producing zones. The lower zone is completed through the tubing and the upper zone through the casing. This is accomplished by a side door choke, which is placed in the tubing above the packer and closed and opened by special tools lowered in the tubing on a steel line. The two zones are acidized separately and then allowed to flow together until clean. There is no additional surface equipment other than the two flow lines to the tanks. In this multizone production, a minimum of critical material is used. The operators are now working on special pumping equipment to meet the requirements for producing either or both reservoirs when pumping is required.

Stephens County

The Chappel limestone reservoir, of Mississippian age, is the principal objective for deeper drilling in the old productive fields and new wildcats. In the Eliasville field (East) the T. P. Coal and Oil Company's No. 12 Hill, sec. 1122, T. E. and L. survey, encountered the Chappel limestone at 4224 to 4230 ft. The well flowed

503 bbl. of 43° gravity oil in 3 hr. In the Eliasville field (West) the T. P. Coal and Oil Company's No. 1C Brown, sec. 114, T. E. and L. survey, drilled the Chappel limestone at 4160 to 4170 ft. The well flowed 165 bbl. of 44° gravity oil in 3 hr. These deeper discoveries should add a considerable quantity to the oil reserves of this old field and additional development of Mississippian limestone is to be expected during 1944 in other old fields of this and adjacent counties.

The Caddo limestone, the Strawn and Marble Falls (Big Saline) sandstone, all of Pennsylvanian age, yielded additional gas reserves during the year.

Taylor County

The West Central Drilling Company's Hudson No. 2, J. A. Nabors survey 9, subdivision 3, was the first well in the Reddin field to be deepened from 2245 ft. to the "Gunsight" limestone. Between 2532 and 2632 are about 40 ft. of saturated limestones. The well was not completed in this zone but is considered a discovery well of the deeper pay. The well originally was completed in the Flippen limestone reservoir and after deepening and acidization was dually completed in this zone at 2242 to 2252 ft. and in the "Lower Hope" zone at 2463 to 2497. On potential test the Flippen reservoir produced by flowing 300 bbl. of 40° gravity oil in 7 hr. through a ¾-in. choke, tubing pressure 100 lb., gas-oil ratio 400:1. The "Lower Hope" reservoir flowed 200 bbl. of 42° gravity oil in 3 hr. through a ¾-in. choke, tubing pressure 150 lb., gas-oil ratio 300:1. By the same operators, Reddin No. 1*A*, an offset to the Hudson No. 2, was then deepened to the "Lower Hope" at 2476 to 2497 ft. and to the "Gunsight" at 2535 to 2560 ft. and dually completed after acidization in these two reservoirs. The "Lower Hope" reservoir on potential test produced by flowing 225 bbl. of 44° gravity oil per hour in 3 hr. through a ¾-in. choke. The "Gunsight" reservoir produced by flowing 15.2 bbl. of 46° gravity oil for 1 hr. through a $\frac{9}{32}$-in. choke, tubing pressure 150 lb., gas-oil ratio 646:1. These are the same prolific zones of the Cisco formation of Pennsylvanian age as are in the Wimberly field, Jones County. The two wells drilled this year to the deeper reservoirs have increased the acreage of the Reddin field about 100 acres and development continues.

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Oil and Gas Development in South Texas during 1943

By Harold Decker* and L. B. Herring,† Members A.I.M.E.

The South Texas area, discussed herein, represents districts 2 and 4 of the Texas Railroad Commission and extends from Jackson, Lavaca, and Gonzales Counties on the northeast to the Rio Grande River, comprising a total of 26 counties.‡ The present boundaries of this district do not coincide with those of earlier reports published in the annual volumes of Petroleum Development and Technology.

The war, in its various ramifications, determined and controlled all the phases of the oil and gas industry. Priorities for material and governmental subsidies determined all new operations.

New Pools

In our opinion, the combined quantity of crude and distillate reserves added in 1943 approached or possibly exceeded the amount produced. Thirty-five new pools were added to the area. Of these, five have significant reserves and ten offer possibilities of containing consequential reserves.

The largest proven reserve discovered during the year was the Slick pool, on the DeWitt-Goliad County line. This is also the most important Wilcox discovery to date in the area.

The most significant extension was at Willimar, Willacy County. Other important extensions were developed at Agua Dulce, Seeligson, and Odem.

Except for the Porter field, in Karnes County, the Laredo trend, which produces from the Jackson and Yegua, proved very disappointing, and this pool is of secondary importance.

The Scott and Hopper pool, Brooks County, has only one well, but offers excellent possibilities of becoming an important discovery. It represents at this time the major Frio discovery of the year.

The Hobson pool, Karnes County, is not a major reserve, but can be classed as important in that it produces at a shallow depth from the Wilcox. This proves that the potential area of production for this zone occupies a broad trend.

Gas and Condensate

During the year construction was begun on only one recycling plant, this being in the Sejita field, Duval County. Several others were contemplated, but no actual operations were begun. The most important development in recycling was the rebuilding of old plants to allow for the fractionation of isopentane, n-butane, isobutane, and propane. Heretofore all pentanes plus have been marketed as "distillate," only a minor portion of the butanes being isolated and sold for fuel purposes. All these new "cuts," except propane, are considered vital to the war effort and propane is being marketed as fuel gas. In other instances propane is being isolated and then pumped back into the gas reservoirs for storage. It is anticipated that the demands for this product will increase in the future.

Drilling in the Wilcox trend during the year showed the existence of valuable gas

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‡ These twenty-six counties are: Bee, Brooks, Calhoun, Cameron, DeWitt, Duval, Goliad, Gonzales, Hidalgo, Jackson, Jim Hogg, Jim Wells, Karnes, Kenedy, Kleberg, Lavaca, Live Oak, Nueces, Refugio, San Patricio, Starr, Victoria, Webb, Willacy, Wilson, Zapata.

and condensate reserves. Sands of this age appear to be destined to furnish this district with appreciable future reserves.

Much interest has been displayed recently in the chemical possibilities of the various components of natural gas. A plant is being built at Bishop, Nueces County, which will use for its base stock butanes and propane recovered by the gas-recycling plant at La Gloria, Jim Wells County. Products to be turned out by this plant are acetic acid, acetone, methanol, and formaldehyde. This is the first chemical operation in the area to take advantage of the concentration of the hydrocarbon constituents available at major recycling plants, and probably is the opening wedge for other similar development.

A major development for the gas industry in this area occurred last year. The Tennessee Gas and Transmission Co. has begun the construction of a pipe line beginning at Agua Dulce, Nueces County, and terminating in West Virginia, to supply the eastern gas market with 200,000,000 cu. ft. of gas daily. This has had a tendency to bolster the values of gas reserves and to cause operators in the Gulf Coastal area to become more "gas" minded.

TRANSPORTATION

One of the main reasons for the small amount of drilling and lower production in 1942 was the lack of adequate outlets for oil from South Texas. In 1943 we saw this condition remedied. Early in the year Sinclair-Prairie completed a pipe line from Corpus Christi to the Houston area, which was the first oil pipe line from South Texas to be built to the Houston area. Later in the year the Defense Plant Corporation converted a gas line from Refugio to Houston, which is now operated by the Humble Pipe Line Co., and this line, plus the rearranging of pipe lines from the Corpus Christi area to Refugio, furnished another major outlet. The latter part of 1943 also saw more tankers transporting crude oil and its products from this area, and for the first time in many years South Texas has adequate outlets for its crude. This will be a major factor in future development of the entire South Texas area.

REFINING

Most of the refineries here have been converted almost exclusively to the manufacturing of war products. Almost all of them have been enlarged. However, owing to various causes, this work has progressed more slowly in this particular area than in most refining centers.

DRILLING

The total number of wells drilled in this district, including wildcat wells, during 1942 and 1943 are shown in Table 5.

This represents a decrease of 10 per cent in the total number of wells drilled and an increase of 3 per cent in the number of dry holes drilled. The number of wildcat wells drilled in 1943 amounted to 13.5 per cent more than in 1942.

The decrease in the total number of wells drilled and the increase in the total number of wildcat wells drilled are probably due to the well-spacing restrictions that were placed on the industry, as well as to the shortage of material for completion of proven locations. During most of the year we were handicapped by a lack of manpower, both in quantity and quality, for our drilling rigs; however, in the latter part of the year the manpower situation eased up some, although the quality of labor was still far below peacetime standards.

During 1943 this district produced 88,421,693 bbl. of oil from 11,211 producing wells, whereas in 1942 it produced 65,791,612 bbl. from 11,143 producing wells. This is an increase of 22,630,081 bbl. of oil, or 34.4 per cent. Almost every field was producing at its maximum capacity without physical waste. Without the discovery of

TABLE 1.—*Oil and Gas Production in South Texas*

Line Number	Field, *County*[a]	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
1	Adami, *Webb*	1939	400	561,671	82,228	249			72	0	3
2	Agua Dulce, *Nueces, Jim Wells*	1928	35,000	4,102,760	1,834,264	302			276	17	7
3	Agua Prieta, *Duval*	1941	20	9,812	1,780	249			1	0	*x*
4	Alamo, *Hidalgo*	1942	160	1,459	*x*	249			*x*	*x*	*x*
5	Albergas, *Webb*	1927	300	2,547,008	2,530	249			8	0	
6	Alfred, *Jim Wells*	1938	500	631,942	167,072	249			24	1	1
7	Alice, *Jim Wells*	1938	1,280	3,173,041	385,321	254			73	0	1
8	East Alice (Tom Graham), *Jim Wells*	1938	1,750	1,785,211	373,782	257			53	0	*x*
9	Alta Mesa, *Brooks*	1926	1,250	1,345,192	154,129	249			44	0	*x*
10	Aransas Pass, *McCampbell, San Patricio, Aransas*	1936	6,200	12,210,430	660,076	249			362	0	*x*
11	Armagosa,* *Jim Wells*	1931	400	gas	*x*	249			9	2	2
12	Armstrong, *Jim Hogg*	1943	100	5,964	5,964	266			2	2	0
13	Aviator, *Webb*	1922	955	6,276,142	84,841	249			232	16	10
14	Baldwin (South Saxet), *Nueces*	1935	500	951,274	76,419	249			14	5	*x*
15	Bandera,* *Jim Wells*	1938	80	1,282		249			2	0	*x*
16	Barbacoas, *Starr*	1933	80	35,504	329	249			14	0	*x*
17	Benavides (North Sweden), *Duval*	1937	3,900	12,665,310	1,166,528	249			278	0	*x*
18	East Benavides, *Duval*	1941	100	20,521	7,422	249			2	0	*x*
19	Ben Bolt, *Jim Wells*	1939	2,100	2,699,870	669,771	249			81	0	*x*
20	Bird Island, *Kleberg*	1938	40	39,148	4,010	268			3	0	*x*
21	Blanchard (Muralla), *Duval*	1939	60	51,167	5,770	249			4	0	*x*
22	Blanconia, *Bee*	1943	300	1,724	1,724	266			6	6	0
23	Blucher, *Jim Wells*	1939	*x*	3,021		249			3	0	1
24	Boyle, *Starr*	1940	300	292,313	124,623	365			17	4	*x*
25	Bridwell, *Duval*	1940	320	149,181	47,230	249			13	2	*x*
26	Brushy Creek, *Lavaca*	1941	80	5,621		249			2	0	*x*
27	Burnell (South), *Karnes*	1937	320	1,073,543	60,543	249			25	0	*x*
28	Caesar, *Bee*	1934	500	1,054,298	20,128	249			42	0	*x*
29	South Caesar, *Bee*	1942	1,000	449,173	360,991	322			21	9	0
30	Cadena, *Duval*	1942	320	69,157	64,513	354			12	9	*x*
31	Calliham (incl. South C.), *McMullen*	1918	890	980,119	41,111	249			142	0	*x*
32	Cameron, *Starr*	1943	100	18,886	18,886	266			2	2	0
33	South Campana, *McMullen*	1941	180	124,285	64,220	249			15	1	*x*
34	Captain Lucey (West Bentonville), *Jim Wells*	1932	220	539,736	26,449	249			23	0	*x*
35	Carolina-Texas, *Webb*	1921	1,500	262,402	*x*	249			66	0	*x*
36	Casa Blanca, *Duval*	1938	550	798,636	219,089	333			58	0	*x*
37	North Casa Blanca, *Duval*	1939	100	146,678	32,205	249			9	0	0
38	West Casa Blanca, *Duval*	1941	160	135,370	50,773	249			20	0	*x*
39	Cedro Hill, *Duval*	1938	770	941,531	227,434	249			81	0	*x*
40	Chapman Ranch, *Nueces*	1937	100	81,950	12,401	249			5	0	0
41	Charamousca (incl. South Ch.), *Duval*	1935	410	872,276	101,095	?			41	0	*x*
42	Charco Redondo, *Zapata*	1913	140	162,166		249			*x*	0	*x*
43	Chiltipin, *Duval*	1939	60	52,541	6,254	249			6	0	*x*
44	Clara Driscoll, *Nueces*	1935	300	1,443,020	162,570	249			30	0	*x*
45	South Clara Driscoll, *Nueces*	1937	2,000	4,221,304	844,210	249			99	0	*x*
46	Collette Creek, *Victoria*	1934	460	1,656,871	147,104	249			50	0	*x*
47	Collier, *Jackson*	1942	320	36,212	36,212	354			3	2	0
48	Colmena, *Duval*	1934	240	572,123	48,221	249			36	0	*x*
49	Cologene, *Victoria*	1939	180	198,514	86,452	249		2,851,226	16	0	*x*
50	Coloma Creek, *Calhoun*	1941	80	51,959	12,018	249			2	0	0
51	Colorado, *Jim Hogg*	1936	3,600	2,872,369	557,464	249			244	13	*x*
52	Comitas (Haynes), *Zapata*	1934	750	1,768,910	106,417	249			196	0	*x*
53	Conoco Driscoll, *Duval*	1924	3,580	5,808,569	1,046,077	249			117	10	0
54	Cordele, *Jackson*	1938	620	2,632,508	270,149	365			50	0	*x*
55	Corpus Christi (Saxet Heights), *Nueces*	1935	160	6,759,232	30,797	249			252	0	*x*
56	Cvellar, *Zapata*	1927	540	2,647,783	13,539	249			86	0	*x*
57	Diamond Half, *Goliad*	1936	240	639,602	20,012	249			22	0	*x*
58	Dinn,* *Duval*	1942	40	*x*	*x*	249			1	0	0
59	Dirks, *Bee*	1934	865	6,287,321	200,739	249			101	0	*x*
60	Duck Bay, (Jay Welder), *Calhoun*	1940	400	168,772	67,722	249			5	1	0
61	Eagle Hill, *Duval*	1933	550	1,885,560	193,037	365			61	0	*x*

[a] Footnotes to column heads and explanation of symbols are given on page 270.

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Secondary Recovery[h]	Character of Oil[i]	Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil: Flowing	Oil: Artificial Lift	Gas		Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
1	0	64	0		20 8	Mirando, Eoc	S	P	975	7	ML	Yegua	1,517
2	99	6	*x*		40 60	Frio, Olig	Sand	25%	4,650	75	AF	Yegua	13,728
3	1	0	0		46	Pettus, Eoc	Sd.	P	4,708	7	NF	Yegua	5,025
4			1		56	Frio	S	P	5,953	*x*	A	Frio	6,567
5	0	8	0		21	Cole, Eoc	Sd.	P	2,125	17	MFL	Yegua	3,700
6	17	5	2		41 46	Frio, M Olig, Vicksburg, Olig	Sd.	P	3,225	20	AF	Yegua	6,535
7	40	12	19		46	Frio, M Olig, Vicksburg, L Olig	Sd.	30–35	3,225	14	NFL	Yegua	6,535
8	35	0	18		42	Frio, M Olig, Vicksburg, L Olig	Sd.	P	3,480	55	ANF	Vicksburg	5,760
9	2	31	3		24	Catahoula, Olig	Sd.	P	2,400	8	DS	Yegua	8,822
10	83	119	48		42 9	Frio, Olig	Sd.	25–34	6,500	9	AF	Frio	10,468
11	0	0	7		gas	Het, Olig	S	P	2,170	10	D	Yegua	6,315
12	2	0	0		37	*x*	S	P	3,240	10	*x*	*x*	3,668
13	0	79	0		21	Mirando, Eoc	S	P	1,525	11	MFL	Cook Mt.	3,975
14	0	13	1		25 9	Catahoula, Olig	S	P	2,900	8	AF	Frio	6,610
15	0	0	2			Yegua, Eoc	S		6,408	8	AF	Yegua	8,302
16	0	1	*x*		24 9	Frio, Olig	S	P	2,450	15	AF	Yegua	6,567
17	96	125	15		43	Cole, Chernosky, Upper Gas Wells, Govt. Wells, Pettus Yegua, L. Eoc	S	27	3,840	19	AFL	Yegua	6,510
18	1	0	0		43	Govt. Wells, Eoc	S	P	4,915	10	AF	Yegua	6,510
19	65	2	12		36–43	Frio, Olig	S	P	4,500	14	ANL	Yegua	6,140
20	1	0	2		44	Frio, Olig	S	P	7,205	8	AF	Frio	9,636
21	2	0	1		43	Pettus, Eoc	S	P	4,683	8	MF	Yegua	5,807
22	2	0	4		25	Frio, Olig	S	P	4,959	6	FS	Frio	5,198
23	0	0	1		58	Frio, Vicksburg	S	P	7,500	20	*x*	Vicksburg	8,004
24	15	1	1		44	Frio, Olig	S	P	3,490	10	AF	Yegua	4,520
25	12	0	0		43 5	Pettus, Eoc	S	P	4,292	8	MF	Yegua	4,657
26			2		54–57	Wilcox, Eoc	S	low	7,680	30	*x*	Wilcox	10,998
27	1	24	0		45	Pettus, Eoc	S	fair	3,650	7	F	*x*	*x*
28	0	16	0		24.7	Cockfield, Eoc	S	P	3,070	15	DF	Yegua	4,230
29	21	0	0		42.2	Wilcox, Eoc	S	P	6,504	20	DF	Wilcox	7,507
30	8	1	2		40	Pettus, Eoc	S	P	5,269	6	AF	Yegua	5,860
31	0	59	0		20	Carrizo, Mirando, Govt. Wells, Loma Novia, Eoc	S	P	848	12	MFL	Carrizo	5,301
32	2	0	0		45.9	*x*	S	P	4,140	*x*	*x*	*x*	*x*
33	14	0	0		22.8	Pettus, Eoc	S	P	1,864	8	MF	Cook Mt.	4,486
34	2	4	9		47	Frio, Vicksburg, Olig	S	P	3,893	11	AF	Yegua	6,500
35		0	7		*x*	Cole, Hackley, Yegua, Eoc	S	*x*	1,200	9	AF	Wilcox	9,228
36	0	49	2		21	Cole, Eoc	S	P	1,180	8	ML	Yegua	2,133
37	0	9	0		21	Cole, Eoc	S	P	1,030	10	ML	Yegua	1,788
38	0	16	1		21	Cole, Eoc	S	P	994	8	ML	Yegua	2,212
39	0	77	1		20	Cole, Eoc	S	P	1,436	10	MFL	Yegua	2,646
40	0	3	2		27.9	Catahoula, Olig	S	P	3,900	10	AF	Frio	7,750
41	1	33	0		20	Cole, McElroy, Eoc	S	P	1,094	8	MFL	Cook Mt.	3,892
42	0	28	0		17	Yegua, Eoc	S	low	200	5	L	*x*	*x*
43	5	0	0		49.6	Pettus, Eoc	S	P	4,760	10	NF	Yegua	5,410
44	10	10	3		23–37	Frio, Olig	S	P	3,800	15	A	Frio	8,055
45	55	39	2		23–40	Catahoula, Het., Frio, Olig	S	P	3,800	10	A	Frio	7,560
46	33	0	2		21	{Frio, Olig Miocene, Mio}	S	P	2,776	10	DF	Yegua	7,860
47	3	0	0		23 6	Miocene, Mio	S	P	2,417	15	D	B. Miocene	5,813
48	0	19	4		21	Cole, Eoc	S	P	1,486	8	ML	Yegua	3,396
49	7	0	6		24 9	Miocene, Mio	S	P	4,600	10	DF	Vicksburg	5,168
50	2	0	0		53.7	Miocene, Mio	S	P	5,880	10	DF	Olig	8,514
51	199	25	0		47.2	Cockfield, Eoc	S	P	2,820	10	ML	Cook Mt.	4,510
52	0	128	0		20.6	McElroy, Eoc	S	P	800	10	ML	Cook Mt.	3,502
53	113	3	1		30	{Frio, Olig Cole, Eoc}	S	P	2,300	13	NL	Cook Mt.	5,390
54	29	16	0		22	{Mirando, Eoc Miocene, Mio}	S	P	2,566	15	DF	Vicksburg	5,117
55	0	11	0		25	Miocene, Mio	S	P	3,974	10	A	Frio	7,531
56	0	24	2		20.9	McElroy, Eoc	S	P	1,525	10	ML	Mt. Selman	4,532
57	0	7	0		40	Cockfield, Eoc	S	P	3,660	14	DF	Yegua	4,540
58	0	0	1		*x*	Mirando, Eoc	S	fair	2,478	4	AL	Yegua	3,006
59	0	86	0		44	Cockfield, Eoc	S	P	3,819	16	DF	Yegua	4,776
60	5	0	0		36.4	Miocene, Mio	S	P	5,654	5	A	Frio	10,002
61	0	51	3		19–22	Cole, Eoc, Govt. Wells, Eoc	S	P	1,450	10	MFL	Yegua	2,752

TABLE 1.—(*Continued*)

Line Number	Field, *County*[a]	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
62	East, *Jim Hogg*	1942	400	37,083	36,906	328			9	8	0
63	Edna, *Jackson*	1937	560	5,172	*x*	249			15	0	0
64	El Tanque (South Rickaby), *Starr*	1937	200	435,115	2,872	249			22	0	*x*
65	Escobas-Jennings, *Zapata*	1914	3,700	10,815,335	494,799	249			539	0	*x*
66	Ezzell, *McMullen, Live Oak*	1937	1,450	2,973,359	243,153	249			151	0	*x*
67	Fagan, *Refugio*	1940	300	75,078	23,550	333			9	0	*x*
68	Fitzsimmons, *Duval*	1938	900	2,860,017	302,776	249			79	0	0
69	Flour Bluff, *Nueces*	1936	2,280	8,046,960	697,956	249			117	0	*x*
70	East Flour Bluff, *Nueces*	1940	1,200	622,494	271,612	249			23	0	*x*
71	Francitas, *Jackson*	1938	1,500	411,245	29,164	249			16	0	0
72	Frost, *Starr*	1942	80	5,271	3,166	249			2	1	0
73	Gallagher, *Jim Well*	1940	160	124,230	48,264	249			4	1	0
74	Ganado (Shallow and Deep), *Jackson*	1937	2,400	963,002	396,446	249			51	10	*x*
75	West Ganado, *Jackson*	1940	1,200	863,738	442,663	302			34	4	*x*
76	Garcia, *Starr*	1942	160	77,067	58,913	324			4	0	0
77	Glen, *Webb, Zapata*	1940	710	1,181,398	358,335	249			75	0	*x*
78	Goebel, *Live Oak*	1943	100	10,177	10,177	284			1	1	0
79	Government Wells, *Duval*	1928	8,500	32,750,467	1,518,236	249			836	1	*x*
80	Green Branch,* *McMullen*	1942	160	*x*	*x*	249			2	1	0
81	Greta, *Refugio*	1933	4,400	30,453,671	1,463,433	249			247	2	*x*
82	Guerra (Cuevitas), *Starr*	1933	400	1,424,073	139,173	333			21	0	*x*
83	Haldeman, *Jim Wells*	1941	60	31,356	12,312	249			2	0	0
84	Harmon, *Jackson*	1942	600	300,086	184,530	305			14	4	0
85	Henne-Winch-Farres, *Jim Hogg*	1924	720	3,215,499	295	249			181	0	*x*
86	Henshaw, *Jim Wells*	1940	50	57,516	17,090	249			4	0	*x*
87	Heyser, *Calhoun, Victoria*	1936	5,500	20,496,231	3,334,434	355			277	0	*x*
88	Hobson, *Karnes*	1943	300	129,350	129,350	278			11	11	0
89	Hoffman, *Duval*	1933	3,400	10,409,064	1,501,885	271			385	0	*x*
90	Holbein, *Jim Hogg*	1940	100	106,683	32,240	249			10	0	0
91	Holzmark, *Bee*	1935	50	69,940	14,497	249			5	0	0
92	Hondo, *Karnes*	1943	50	31,642	31,642	?			1	1	0
93	Hordes Creek, *Goliad*	1940	100	76,809	7,314	?			7	0	*x*
94	Jacob (incl. North Jacob), *McMullen*	1926	1,230	1,736,045	84,885	249			129	0	*x*
95	Keeran, *Victoria*	1932	1,350	1,838,690	198,946	249			21	0	0
96	Kelsey, *Jim Hogg, Starr, Brooks*	1938	2,300	2,546,042	543,214	333			120	0	*x*
97	Little Kentucky, *Jackson*	1943	50	2,655	2,655	258			1	1	0
98	Killam, *Webb*	1937	950	1,248,767	155,847	249			133	0	*x*
99	North Killam (incl. Hauser), *Webb*	1938	80	76,116	7,132	249			7	0	*x*
100	Kingsville, *Kleberg*	1920	240	765,263	10,017	249			20	0	*x*
101	Kohler (incl. Deep Kohler), *Duval*	1926	360	692,050	10,726	249			95	0	*x*
102	Koopman, *Jim Wells*	1942	80	25,166	14,784	249			3	1	*x*
103	Kreis, *Duval*	1940	200	128,996	60,845	302			9	0	0
104	Labbe, *Duval*	1934	230	475,203	48,815	284			31	0	*x*
105	La Blanca,* *Hidalgo*	1936	4,000	617,742	*x*	249			7	0	0
106	La Gloria, *Jim Wells, Brooks*	1939	4,500	76,021	14,406	249			43	2	*x*
107	La Reforma, *Starr*	1938	40	30,058	4,493	249			5	0	0
108	La Rosa, *Refugio*	1938	1,720	4,353,244	637,836	257			96	0	*x*
109	North La Rosa, *Refugio*	1943		*x*	*x*	249			1	1	0
110	Las Animas, *Jim Hogg*	1937	100	71,803	16,780	249			11	0	*x*
111	Laurel, *Webb*	1932	220	628,546	2,656	249			33	0	*x*
112	North La Ward, *Jackson*	1941	4,000	1,319,160	742,545	249			96	27	*x*
113	Lockhart, *Starr*	1943	500	72,617	72,617	304			11	11	0
114	Lolita, *Jackson*	1940	3,100	5,835,338	1,886,416	249			176	0	0
115	Loma Alta, *McMullen*	1935	80	178,267	15,825	249			4	0	*x*
116	Loma Novia, *Duval*	1934	7,410	28,369,220	1,609,837	249			758	0	*x*
117	Loma Vista, *Duval*	1936	10	18,586	1,978	249			2	0	*x*
118	London, *Nueces*	1937	80	112,157	15,013	249			4	0	*x*

TABLE I.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Secondary Recovery[h]	Character of Oil[i]	Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil		Gas		Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift											
62	9	0	0		51	Cockfield, Eoc	S	P	4,741	10	A	Yegua	5,303
63	6	0	9		*x*	*x*	S	P	2,640	20	D	Cockfield	7,180
64	0	15	0		23	Frio, Olig	S	P	425	8	NL	Yegua	2,700
65	0	332	2		20	Yegua, Eoc	S	P	900	12	AFL	Mt. Selman	4,645
66	0	127	1		20	Loma Novia, Eoc	S	P	1,490	8	ML	Cook Mt.	3,108
67	4	0	1		28.6	Miocene, Mio Frio, Olig	S	P	2,118	10	DF	Olig	7,200
68	59	19	1		46	McElroy, Pettus, Eoc	S	P	3,592	10	MF	Yegua	5,285
69	68	22	5		43	Marginulina, L Olig	S	P	6,590	25	AF	Frio	7,504
70	20	0	1		41.6	Marg., L Olig	S	P	6,753	8	AF	Frio	8,694
71	11	0	5		50	Frio, Olig	S	P	7,378	15	D	Vicksburg	10,665
72	2	0	0		45	Frio, Olig	S	P	4,181	8	ML	Vicksburg	5,435
73	4	0	0		39	Frio, Vicksburg, Olig	S	P	5,189	*x*	NFL	Yegua	6,260
74	50	1	0		25–35	Marg., Frio, Olig	S	P	5,080	15	DF	Frio	7,635
75	30	0	0		24	Frio, Olig	S	P	4,760	10	DF	Vicksburg	7,635
76	4	0	0		42	Frio, Olig	S	P	3,740	6	AF	Frio	4,075
77	23	48	1		22	Mirando, Eoc	S	P	2,160	12	NL	Yegua	3,240
78	1	0	0		38	Wilcox, Eoc	S	P	7,054	10	*x*	Wilcox	7,095
79	0	639	2		21	Cole, Het., Govt. Wells, Mirando, Yegua, Eoc	S	P	1,550	17	NFL	Mt. Selman	5,858
80	1	0	1		28	Wilcox, Eoc	S	P	5,720	6	*x*	Navarro	7,623
81	203	0	0		23-39	Miocene, Mio Het., Mio Frio, Olig	S	20-33	3,500	15	A	Vicksburg	7,473
82	9	3	0		33	Cole, McElroy, Eoc	S	P	1,745	14	MF	Yegua	3,600
83	1	1	0		33	Frio, Olig	S	P	5,019	11	NF	Yegua	6,498
84	14	0	0		28.8	Frio, Olig	S	P	5,320	10	T	Frio	6,717
85	0	1	0		20	Mirando, Eoc	S	P	1,944	16	MFL	Yegua	3,546
86	1	1	0		31, 53	Frio, Vicksburg, Olig	S	P	3,778	11	NF	Vicksburg	5,885
87	200	28	0		31-43	Miocene, Mio Frio, Olig	S	P	5,400	25	A	Frio	6,487
88	11	0	0		32	Wilcox, Eoc	S	25–30	4,000	20	AF	Basal Wilcox	7,474
89	4	333	7		22-25	Hockley, Govt. Wells, Loma Novia, Cockfield, Eoc	S	P	2,550	17	AF	Yegua	3,800
90	10	0	0		24.5	Pettus, Eoc	S	P	2,793	10	NL	Yegua	3,150
91	5	0	0		40–50	Hockley, Yegua, Eoc	S	P	3,500	5	DF	Cockfield	4,458
92	1	0	0		48.8	Wilcox, Eoc	S	P	6,580	15	*x*	Wilcox	6,580
93	1	0	0		43	Yegua, Eoc	S	P	4,545	10	DF	Cook Mt.	6,004
94	0	71	0		21	Mirando, Pettus, Yegua, Eoc	S	P	780	8	ML	Mt. Selman	3,171
95	21	0	0		26–40	Frio, Olig	S	15	4,800	10	A	Vicksburg	10,043
96	108	2	1		44	Frio, Olig Govt. Wells, Eoc Yegua, Eoc	S	P	4,671	13	A	Yegua	7,507
97	1	0	0		35.4	Frio, Olig	S	P	5,700	10	*x*	Frio	5,700
98	0	88	0		21	Mirando, Cockfield, Eoc	S	P	1,920	13	ML	Yegua	3,011
99	0	4	0		22	Mirando, Cockfield, Eoc	S	P	2,046	15	ML	Yegua	3,060
100		1	0		21	Miocene, Mio Catahoula, Olig	S	P	1,400	20	D	Frio	6,922
101	8	1	6		22	Cole, Govt. Wells, Mirando, Eoc	S	P	1,748	14	ML	Carrizo	7,723
102	1	0	1		44.5	Frio	S	P	4,112	10	ML	Vicksburg	6,016
103	0	9	0		31	Mirando, Eoc	S	P	3,200	12	NL	Yegua	4,732
104	2	10	4		25	Cole, Chemosky, Loma Novia, Eoc	S	P	1,872	12	ML	Yegua	4,054
105	0	0	7		55	Frio	S	tight	7,500	40	A	Frio	8,890
106	2	0	27		39-55	Frio, Vicksburg, Olig	S	P	5,888	19	A	Yegua	8,043
107	1	0	4		42	Frio, Vicksburg, Olig	S	P	5,917	40	AF	Jackson	7,010
108	83	0	8		29–39	Frio, Olig	S	P	5,400	12	DF	Vicksburg	8,020
109	1	0	0		50	Frio, Olig	S	P	6,180	10	*x*	*x*	*x*
110	1	6	1		18.5	Cole, Eoc	S	P	1,782	22	NL	Yegua	4,014
111	0	4	0		49	Frio, Mirando, Cockfield, Eoc	S	P	360	6	MFL	Cook Mt.	3,165
112	96	0	0		26	Marg., Frio, Olig	S	P	5,200	7	DF	Vicksburg	7,735
113	9	1	1		46.6	Cockfield, Yegua	S	P	3,600	8	*x*	Yegua	4,600
114	176	0	0		26-33	Marg., Frio, Olig	S	P	5,200	9	D	Frio	7,280
115	0	3	0		21	Chemosky, Eoc	S	P	2,195	12	MFL	Cockfield	2,766
116	0	554	1	G	23	Loma Novia, Mirando, Eoc	S	P	2,550	20	ML	Cook Mt.	4,200
117	1	0	0		25.7	Loma Novia, Eoc	S	P	2,914	7	ML	Cook Mt.	4,732
118	0	3	0		24.4	Catahoula, Olig	S	P	4,698	8	NF	Frio	7,424

TABLE 1.—(*Continued*)

Line Number	Field, County[a]	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
119	Longhorn, *Duval*	1938	1,000	2,222,143	365,587	24)			49	1	*x*
120	Lopena,* *Zapata*	1934	1,100	gas	gas	249			23	0	*x*
121	Lopez, *Webb, Duval*	1935	3,450	13,405,285	945,554	249			369	0	*x*
122	Los Olmos, *Starr*	1925	240	656,901	10,605	249			110	0	*x*
123	Luby (incl. Luby Deep), *Nueces*	1937	3,000	8,874,999	1,222,719	249			153	0	*x*
124	North Luby, *Nueces*	1939	80	124,219	26,711	249			5	0	*x*
125	Mt. Lucas, *Live Oak*	1923	120	343,739	13,790	249		523,932	32	0	*x*
126	Lundell, *Duval*	1937	940	1,772,434	338,116	249			104	0	*x*
127	Lykes, *Webb*	1942	20	1,629	720	249			1	0	0
128	Magnolia City, *Jim Wells*	1939	120	202,493	22,402	267			9	0	*x*
129	North Magnolia City, *Jim Wells*	1943	200	*x*	*x*	293			4	4	0
130	Manila, *Jim Hogg*	1940	230	270,978	46,387	249			26	0	*x*
131	Martinez (incl. South Martinez),* *Zapata*	1929	850	gas	gas	249			27	0	*x*
132	Mathis East, *San Patricio*	1924	300	14,108	232	249			2	0	0
133	Maubro, *Jackson*	1941	3,275	1,112,577	403,367	249			71	*x*	0
134	Mauritz, *Jackson*	1935	200	682,491	106,118	284			8	0	0
135	West Mauritz, *Jackson*	1942	500	271,808	236,937	339			13	6	0
136	Mayo, *Jackson*	1942	1,600	429,275	329,655	273			32	11	*x*
137	McAllen, Pharr,* *Hidalgo*	1938	960	16,596	*x*	249			4	0	0
138	McFaddin, *Victoria*	1930	1,000	5,437,811	1,747,812	249			93	0	*x*
139	McFaddin-North, *Victoria*	1937	100	116,918	47,927	249			22	0	0
140	McLean, *Webb*	1942	200	129,182	66,902	249			5	0	0
141	McNeill, *Live Oak*	1934	180	287,750	9,791	249			7	0	*x*
142	Melon Creek, *Refugio*	1939	210	751,782	191,293	365			10	0	0
143	Mercedes (Capsillo), *Hidalgo*	1935	560	191,431	*x*	249			7	0	0
144	Midway, *San Patricio*	1937	1,860	3,515,811	1,086,254	249			73	5	*x*
145	Minnie Boch (ind. Gandy), *Nueces*	1939	1,640	2,568,246	745,357	?			86	0	*x*
146	Mirando City, *Webb*	1921	1,430	9,393,099	93,188	249			295	0	*x*
147	Mirando Valley, *Zapata*	1921	1,000	1,561,858	75,213	249			146	0	*x*
148	Mission River, *Refugio*	1938	381	1,872,641	247,465	365			17	0	0
149	Moca, *Webb*	1932	100	1,243,290	55,296	365			12	0	*x*
150	Munson, *McMullen*	1938	150	197,410	15,966	249			17	0	*x*
151	Neuhaus, *Jim Hogg*	1941	80	22,196	12,405	249			2	0	0
152	Nichols, *Hidalgo*	1)40	280	296,838	116,280	365			15	0	*x*
153	Normanna, *Bee*	1930	70	101,816	3,982	249			7	0	*x*
154	Oakville, *Live Oak*	1937	400	1,029,206	179,740	365			46	1	*x*
155	Odem, *San Patricio*	1939	2,200	1,058,307	649,193	249			60	12	0
156	Oilton, *Webb*	1937	525	1,724,038	68 306	249			141	0	*x*
157	Orange Grove, *Jim Wells*	1940	1,040	1,630,113	514,100	329			40	0	*x*
158	Penitas,* *Hidalgo*	1942	1,000	*x*	*x*	249			1	0	0
159	Peters, *Duval*	1933	300	259,935	23,061	249			21	0	*x*
160	East Peters, *Duval*	1940	60	33,884	8,197	249				0	0
161	Petronilla, *Nueces*	1941	1,000	100,272	62,577	249			8	2	*x*
162	Old Pettus, *Bee*	1929	1,200	9,086,717	66,202	249			91	1	*x*
163	New Pettus, *Bee-Goliad-Karnes*	1930	1,000	3,548,692	143,679	249			53	1	*x*
164	Piedre Lumbre, *Duval*	1935	1,300	4,027,002	791,409	249			144	0	*x*
165	Placedo, *Victoria*	1935	3,000	15,109,832	1,459,436	249			182	0	*x*
166	East Placedo, *Victoria*	1937	600	833,707	252,371	249			32	2	*x*
167	Plummer, *Bee*	1937	160	275,902	3,198	365			15	0	*x*
168	Plymouth, *San Patricio*	1935	3,750	29,170,754	3,426,633	365			201	0	*x*
169	East Plymouth,* *San Patricio*	1938	640	*x*	*x*	249			4	3	0
170	Porter, *Karnes*	1943	400	78,243	78,243	249			13	13	0
171	Premont (incl. SE. Premont), *Jim Wills*	1933	720	818 621	29,506	249			63	0	*x*
172	South Premont,* *Jim Wells*	1942	40	*x*	*x*	249			1	0	0
173	Quinto Creek, *Jim Wells*	1942	80	48,362	35,030	354			4	1	*x*
174	Rancho Solo. (incl. Rancho Solo Extension), *Duval*	1935	440	303,837	28,847	249			45	0	*x*
175	Randado, *Jim Hogg*	1926	765	4,945,891	58,677	249			191	0	*x*
176	Ray, *Bee*	1935	420	1,615,265	26,562	249			42	0	*x*
177	Refugio, *Refugio*	1922	8,500	41,470,568	1,428,427	249			500	0	*x*
178	Refugio Fox, *Refugio*	1931	850	4,315,243	88,396	249			17	1	0
179	Reynolds, *Jim Wells*	1939	690	1,375,923	181,744	249			32	0	*x*
180	Rhode,* *McMullen*	1936	1,200	*x*	*x*	249	*x*	*x*	11	0	*x*
181	Ricaby (incl. N. Ricaby), *Starr*	1937	150	151,072	22,805	249			14	0	*x*

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Secondary Recovery[h]	Character of Oil[i]	Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil				Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift	Gas										
119	29	14	0		45	Cole, Govt. Wells, Eoc	S	P	4,009	10	AFL	Yegua	6,011
120	0	0	21		gas	Queen City, Eoc	S	P	2,137	20	A	Mt. Selman	3,707
121	1	310	1		20.7	Mirando, Eoc	S	P	2,126	18	ML	Yegua	3,437
122	0	75	0		20	Frio, Olig	S	P	250	17	MF	Yegua	2,612
123	133	12	5		37–46	Catahoula, Het., Frio, Olig	S	30	4,300	15	AF	Frio	7,595
124	0	3	0		48	Catahoula, Het., Olig	S	P	4,300	10	AF	Frio	7,300
125	0	3	12		23	Frio, Olig Yegua, Eoc	S	P	2,510	20	D	Cook Mt.	6,789
126	34	60	3		19	Cole, Eoc	S	P	1,500	10	MFL	Yegua	2,698
127	0	1	0		45	Mirando, Eoc	S	P	1,950	14	ML	Yegua	2,638
128	2	1	0		42	Frio, Olig	S	P	5,436	9	A	Yegua	6,592
129	4	0	0		34.8	Frio	S	P	3,628	10	*x*	Vicksburg	6,015
130	2	21	2		24.9	Pettus, Eoc	S	P	2,541	10	NL	Yegua	3,006
131	0	0	18		gas	McElroy, Eoc	S	P	1,860	6	ML	Cook Mt.	3,514
132	0	0	2		35	Frio, Vicksburg, Olig	S	P	4,400	9	NF	Yegua	6,348
133	71	0	0		24.4	Frio, Olig	S	P	5,220	10	D	Frio	6,520
134	8	0	0		31.4	Frio, Olig	S	P	5,650	10	D	Vicksburg	7,808
135	13	0	0		33.8	Frio, Olig	S	P	5,470	10	DF	Frio	6,760
136	32	0	1		29	Frio, Olig	S	P	5,100	10	DF	Vicksburg	7,808
137	0	0	4		60	Frio, Olig	S	P	5,970	23	AF	Vicksburg	8,575
138	75	13	*x*		20–40	Het., Frio, Olig	S	P	4,400	15	AF	Frio	7,025
139	5	0	17		38–47	Frio, Olig	S	P	5,350	10	A	Frio	7,506
140	0	5	0		55	Yegua, Eoc	S	P	3,238	15	NL	Cook Mt.	4,016
141	2	0	0		44.3	Hockley, Jackson	S	P	4,434	10	D	Cook Mt.	6,212
142	10	0	0		35.4	Frio, Olig	S	P	5,856	20	D	Frio	5,876
143	0	0	7		49	Frio, Olig	S	P	7,430	15	DF	Vicksburg	9,618
144	57	10	2		38	Het., Frio, Olig	S	P	5,285	19	AF	Vicksburg	10,004
145	36	38	3		23	Catahoula, Olig, Frio	S	P	3,652	10	AF	Frio	7,510
146	0	63	1		20	McElroy, Cockfield, Eoc	S	P	1,530	10	ML	Mt. Selman	5,000
147	2	66	1		20	McElroy, Mirando, Eoc	S	P	1,400	9	ML	Cook Mt.	3,660
148	17	0	0		31–41	Frio, Olig	S	P	5,183	10	D	Vicksburg	9,225
149	0	11	0		21	Mirando, Eoc	S	P	900	10	MFL	Yegua	2,178
150	0	12	0		22	Mirando, Eoc	S	P	1,200	12	ML	Pettus	1,501
151	1	1	0		47	Pettus, Eoc	S	P	3,454	9	MF	Pettus	3,471
152	10	4	0		34	Frio, Olig	S	30	3,132	8	AF	Yegua	5,482
153	1	2	0		37.7	Yegua, Eoc	S	P	3,500	17	D	Yegua	5,038
154	0	29	0		20–24	Miocene, Mio Yegua, Olig Cockfield, Eoc	S	P	1,830	8	AF	Cook Mt.	4,500
155	55	1	4		35	Catahoula, Het., Frio, Olig	S	30	3,500	24	AF	Frio	7,517
156	0	68	0		22	Mirando, Cockfield, Eoc	S	P	1,880	13	ML	Yegua	3,151
157	30	6	0		32	Frio, Olig	S	P	3,292	15	NF	Yegua	6,012
158	0	0	1		60	Vicksburg, Olig	S	P	6,020	20	FA	Vicksburg	6,802
159	1	3	7		23	Cole, Govt. Wells, Mirando, Eoc	S	P	1,750	13	ML	Cook Mt.	4,004
160	1	3	0		22.9	Govt. Wells, Eoc	S	P	2,441	13	ML	Mirando	2,563
161	7	0	0		40	Frio, Olig	S	P	6,952	9	NF	Frio	10,020
162	0	29	0		44.7	Cockfield, Eoc	S	P	3,900	19	DF	Wilcox	8,993
163	49	0	*x*		46.6	Cockfield, Eoc	S	P	3,900	15	DF	Cook Mt.	7,569
164	9	121	0		22	Cole, Govt. Wells, Loma Novia, Eoc	S	P	1,324	10	ML	Midway	10,931
165	50	104	*x*		22–29	Het., Frio, Olig	S	P	4,700	15	AF	Frio	7,242
166	27	0	0		38	Frio, Olig	S	P	6,000	10	AF	Frio	7,502
167	0	1	0		30	Cockfield, Eoc	S	P	3,050	5	DF	Cook Mt.	4,756
168	174	14	3		31	Frio, Olig	S	P	5,458	10	AF	Frio	7,253
169	0	0	4		gas	Het., Frio, Olig	S	28–34	4,808	17	AF	Frio	7,287
170	12	1	0		48	Pettus, Eoc	S	P	3,950	10	AF	Wilcox	8,015
171	2	18	1		23	Catahoula, Frio, Olig	S	P	2,250	10	D	McElroy	7,155
172	0	0	1		*x*	Frio, Olig	S	P	6,040	18	*x*	Vicksburg	7,631
173	2	0	1		29	Frio, Vicksburg, Olig	S	P	4,860	13	NF	Yegua	5,900
174	0	35	0		19	Cole, Govt. Wells, Eoc	S	P	1,800	10	ML	Yegua	3,777
175	0	82	0		19	Cole, Eoc	S	P	1,220	10	NL	Mt. Selman	5,222
176	0	10	0		46	Cockfield, Eoc	S	P	3,920	15	DF	Yegua	4,253
177	101	42	*x*		23–40	Catahoula, Frio, Olig	S	30	3,700	15	DF	Vicksburg	9,373
178	16	0	1		33.9	Marginulina, Olig	S	34	5,890	10	D	Frio	7,300
179	19	7	1		35	Frio, Olig	S	P	3,145	10	ANL	Yegua	6,025
180	0	0	9		gas	Cole, Eoc	S	P	1,800	12	MFL	Yegua	3,534
181	0	9	0		21	Frio, Olig	S	P	1,270	7	NL	Yegua	2,844

TABLE 1.—(*Continued*)

Line Number	Field, County[a]	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Producing Days, 1943[d]	Gas Production, Millions Cu Ft.[e]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
182	Richard King (East Bentonville), *Nueces*	1937	2,000	2,897,251	959,981	249			82	5	*x*
183	Rincon, *Starr*	1938	4,500	5,940,017	2,327,114	293			162	7	*x*
184	North Rincon, *Starr*	1940	400	209,023	77,941	302			15	1	0
185	Rio Grande City, *Starr*	1932	200	447,539	13,545	249			34	0	*x*
186	Rios,* *Duval*	1941	20	*x*	*x*	249	*x*	*x*	1	0	0
187	Riverside, *Nueces*	1938	2,000	137,056	24,804	249			7	1	*x*
188	Robstown, *Nueces*	1939	200	110,419	31,838	249			7	2	*x*
189	Rook, *San Patricio*	1942	200	*x*	*x*	249			5	2	0
190	Ross, *Starr*	1943	640	4,878	4,878	258			4	4	0
191	Sam Fordyce (incl. North Sam Fordyce), *Hidalgo, Starr*	193	1,600	7,588,772	100,412	365			259	0	*x*
192	Sandia,* *Jim Wells*	1929	80	29,242	*x*	249			9	0	*x*
193	San Salvador (incl. Mestinas),* *Hidalgo*	1938	1,200	*x*	*x*	249	*x*	*x*	7	0	*x*
194	Sarnosa, *Duval*	1932	690	2,782,208	116,154	249			57	0	*x*
195	Saxet (Deep) (Frio), *Nueces*	1935	2,450	25,508,543	1,186,450	249			761	*x*	*x*
196	Saxet (Shallow), *Nueces*	1923	3,850	30,729,855	1,309,321	249				0	*x*
197	Seeligson (East Premont), *Jim Wells, Kleberg*	1937	9,300	2,249,297	1,529,659	249			185	56	0
198	Sejita, *Duval*	1939	4,000	140,577	127,510	284			22	10	0
199	Seven Sisters, *Duval*	1934	4,420	19,548,052	1,844,588	365			461	0	*x*
200	South Seven Sisters, *Duval*	1937	330	732,645	40,887	249			33	0	*x*
201	Shield, *Nueces*	1940	2,100	387,152	133,004	249			15	0	*x*
202	Sinton (incl. South Sinton), *San Patricio*	1934	300	71,240	0	249			8	0	*x*
203	Slick-Wilcox, *Goliad*	1943	1,000	62,149	62,149	293			7	7	0
204	Southland, *Duval*	1939	350	181,091	49,224	302			5	0	*x*
205	Stewart, *Jackson*	1942	350	97,576	74,114	259			7	1	0
206	Strake, *Duval*	1943	120	*x*	*x*	312			3	3	0
207	Stratton (incl. East Stratton), *Nueces, Kleberg, Jim Wells*	1931	13,500	3,175,853	1,715,236	249			208	25	*x*
208	Sullivan City, *Hidalgo, Starr*	1939	780	604,808	113,336	249			39	0	*x*
209	Sun, *Starr*	1938	2,400	1,964,097	804,225	249			88	1	*x*
210	North Sun, *Starr*	1941	1,000	262,074	236,956	312			26	16	0
211	Sun-Jones (Jones),* *Jim Hogg*	1941	20	0	0	249	*x*	*x*	1	0	0
212	Sweden, *Duval*	1937	1,500	267,996	15,719	249			15	0	*x*
213	Taft, *San Patricio*	1935	720	5,817,154	462,509	333			74	0	*x*
214	Tarancahuas, *Duval*	1939	290	610,964	201,895	302			29	0	*x*
215	Telferner, *Victoria*	1938	30	67,046	4,480	249			4	0	*x*
216	Tesora (De Soto), *Duval*	1938	140	220,576	11,000	249			8	0	*x*
217	Texana, *Jackson*	1939	300	35,811	4,580	249		1,661,069	3	0	0
218	Tom O'Connor, *Refugio*	1934	12,000	46,683,560	12,690,095	264			451	0	*x*
219	Tuleta, *Bee*	1932	1,160	1,961,622	20,017	249			75	0	*x*
220	Tulsita, *Bee*	1938	120	11,616	1,401	249			12	0	*x*
221	Turkey Creek (West Saxet), *Nueces*	1938	12,000	4,766,501	468,620	249			60	0	*x*
222	Tynan, *Bee*	1942	40	5,035	5,035	344			1	0	0
223	Victoria, *Victoria*	1940	300	367,178	58,145	365			26	0	*x*
224	Volpe, *Webb*	1939	330	599,634	126,137	249			34	0	*x*
225	Wade City, *Jim Wells*	1939	2,000	3,866,097	945,954	249			107	1	*x*
226	Weil, *Jim Hogg*	1943	240	10,822	10,822	266			1	1	0
227	Weser, *Goliad*	1936	140	32,262	4,201	249			10	0	*x*
228	West Ranch, *Jackson*	1938	10,000	17,882,168	6,826,213	293			390	13	0
229	White Creek, *Live Oak*	1939	400	403,793	70,559	302			35	0	*x*
230	South White Creek, *Live Oak*	1941	100	148,518	83,511	249			7	2	0
231	White Point, *San Patricio*	1911	2,100	202,833	24,680	365			48	0	*x*
232	East White Point, *San Patricio, Nueces*	1938	4,800	15,076,018	3,851,559	352			251	5	*x*
233	Willamar, *Willacy*	1940	6,000	186,867	122,562	249			11	4	0
234	Woodsboro, *Refugio*	1941	300	137,042	78,768	249			7	4	0
235	Yeager, *Jim Hogg*	1943	200	27,293	27,293	293			4	4	0
236	Young* (Charco Blanco), *Starr*	1938	20	*x*	*x*	249			1	0	0
237	Yturria, *Starr*	1941	760	201,888	134,922	249			13	1	*x*
238	Yzaguirre, *Starr*	1940	40	5,243	668	249			2	0	*x*

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Secondary Recovery[h]	Character of Oil[i]	Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil												
	Flowing	Artificial Lift	Gas		Gravity A.P.I. at 60°F.	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
182	70	7	3		22–56	Frio, Vicksburg, Olig	S	P	3,800	10	AF	Yegua	7,576
183	145	5	5	PM	40	Frio, Vicksburg, Olig	S	26–39	3,629	19	A	Yegua	6,862
184	7	3	5		42	Frio, Vicksburg, Yegua, Olig	S	P	4,111	14	A	Yegua	5,590
185	0	20	0		29	Frio, Olig	S	P	1,350	8	MFL	Yegua	3,258
186	0	0	1		*x*	McElroy, Eoc	S	P	6,270	15	NF	McElroy	6,308
187	2	0	3		32	Frio, Olig	S	30	5,000	15	A	Frio	7,750
188	5	0	0		41–52	Frio, Olig	S	*x*	5,195	11	A	Frio	7,525
189	5	0	0		39	Frio, Olig	S	P	7,135	15	*x*	Frio	7,165
190	4	0	0		26	*x*	S	P	2,520	*x*	*x*	*x*	*x*
191	1	43	0		24	Frio, Olig	S	P	2,737	16	AF	Mt. Selman	9,708
192	0	0	4		Gas	Catahoula, Frio, Olig	S	P	2,910	10	AF	McElroy	5,701
193	0	0	5			Cole, Eoc Frio, Olig	S	P	7,315	15	A	Vicksburg	8,704
194	0	36	0		21.3	Govt. Wells, Eoc	S	P	2,300	15	MFL	Yegua	4,073
195	26	53	0		30–40	Frio, Olig	S	*x*	5,200	10	DF	Vicksburg	10,892
196	24	181	0		24–31	Catahoula, Het., Olig	S	30	3,900	18	DF	Vicksburg	10,892
197	176	1	8		36–50	Frio, Olig	S	P	4,900	20	A	Vicksburg	8,162
198	15	0	7		44	McElroy, Eoc	S	P	5,334	17	AF	Yegua	7,095
199	8	379	9		23	Frio, Olig	S	P	1,232	23	AFL	Yegua	4,404
200	0	23	0		22	Frio, Olig Loma Novia, Eoc	S	P	1,487	9	AFL	Yegua	3,100
201	10	0	4		44.3	Frio, Olig	S	P	6,600	12	AF	Frio	7,806
202	0	0	3		53	Frio, Olig	S	P	3,260	22	A	Frio	7,438
203	7	0	0		36.4	Wilcox, Eoc	S	P	7,560	50	DF	Wilcox	7,560
204	3	0	1		43.8	Pettus, Eoc	S	P	5,298	10	AFL	Yegua	6,015
205	7	0	0		26	Frio, Olig	S	P	4,950	10	DF	Olig	7,508
206	3	0	0		23.6	Jackson	S	P	3,180	5	*x*	*x*	3,238
207	154	0	42		43	Frio, Olig	S	P	4,788	17	AF	Vicksburg	8,138
208	19	3	4		25–39	Frio, Olig	S	P	3,300	15	AF	Mt. Selman	9,708
209	82	0	4		45	Frio, Olig	S	P	3,900	10	A	Yegua	6,113
210	26	0	0		46	Frio, Vicksburg, Olig	S	P	4,500	*x*	A	*x*	8,470
211	0	0	1		Gas	Hock., Eoc	S	P	4,211	15	*x*	Yegua	6,009
212	1	2	2		43	Chernosky, Govt. Wells, Cockfield, Eoc	S	P	4,900	12	AFL	Yegua	7,005
213	47	21	1		23	Catahoula, Mio Het., Olig	S	P	3,975	20	MF	Frio	6,926
214	1	26	0		21	Frio, Olig	S	P	2,050	15	NFL	Yegua	3,461
215	0	2	0		28	Frio, Olig	S	P	2,693	5	DF	Cook Mt.	7,666
216	2	0	0		46.8	Pettus, Yegua, Eoc	S	P	4,828	15	NF	Yegua	5,541
217	1	0	2		25	Frio, Olig	S	P	5,102	10	D	Vicksburg	8,724
218	449	0	0		35.5	Frio, Olig	S	P	5,600	175	AFL	Frio	8,174
219	0	17	*x*		39	Jackson, Pettus, Eoc	S	P	3,065	11	DF	Wilcox	7,921
220	0	1	0		45	Cockfield, Eoc	S	P	3,632	10	DF	Cockfield	3,598
221	29	18	1	PM	20–38	Catahoula, Mio Frio, Olig	S	P	3,860	8	DF	Frio	7,511
222	1	0	0		45	Frio, Olig	S	P	4,199	3	*x*	Frio	4,750
223	0	14	*x*		27	Catahoula, Olig	S	P	2,550	10	DLF	Vicksburg	5,252
224	6	22	*x*		21	Mirando, Eoc	S	P	2,450	12	MFL	Yegua	3,717
225	91	0	0		32	Frio, Vicksburg, Olig	S	P	4,800	10	NFL	Yegua	5,410
226	1	0	0		46	*x*	S	P	5,050	10	*x*	*x*	5,058
227	0	1	*x*		43.6	Yegua, Eoc	S	P	5,240	10	F	Cook Mt.	5,313
228	385	5	*x*		26–40	Het., Marg., Frio, Olig	S	P	5,100	24	DF	Vicksburg	8,527
229	0	31	*x*		21.7	Yegua, Eoc	S	P	1,400	7	DLF	Yegua	1,785
230	7	0	0		20.4	Yegua, Eoc	S	P	1,814	8	SL	Yegua	3,382
231	0	1	4		24.8	Oakville, Mio; Het., Olig Frio, Olig	S	P	1,900	8	AF	Frio	7,211
232	234	4	6		38.7	Oakville, Mio; Het., Olig Catahoula, Olig; Frio, Olig	S	P	2,495	17	AF	Frio	8,483
233	11	0	0		30	Marg., Olig	S	P	7,600	40	AF	Frio	9,003
234	7	0	0		40	Frio, Olig	S	P	5,800	5	DF	Frio	6,710
235	4	0	0		36.5	Eoc	S	P	3,750	10	A	*x*	3,770
236	0	0	1		Gas	Mirando, Eoc	S	P	2,708	15	MF	Cockfield	3,008
237	11	0	0		43.3	Frio, Olig	S	P	4,210	10	MF	Yegua	4,889
238	1	0	0		48	Frio, Olig	S	P	4,600	10	*x*	Yegua	6,006

substantial reserves, we cannot expect to increase this production in 1944, and by the latter half of this year we shall see many good fields unable to maintain their state

TABLE 2.—*Summary of Drilling Operations in South Texas*

Important Wildcats Drilled in 1943

	Pool Name	County	Top of Pay, Ft.	Total Depth, Ft.	Surface Formation
1	Blanconia	Bee	4,937	5,605	Lissie
2	Cosden-Wilcox	Bee	7,398	7,516	Goliad
3	Cosden-West	Bee	3,645	3,650	Goliad
4	Mineral	Bee	7,478	7,893	Goliad
5	Tynan	Bee	4,213	4,752	Lissie
6	Scott and Hopper[a]	Brooks	6,587 6,872	6,912	Lissie
7	Clara	Duval	3,768	3,845	Reynosa
8	E. Fitzsimmons	Duval	4,651	4,857	Reynosa
9	Strake[a]	Duval	3,723 3,168	4,010	Reynosa
10	Cabeza Creek	Goliad	7,743	8,982	Goliad-Largato
11	Terrell Point	Goliad	4,650	5,204	Lissie
12	Slick-Wilcox	Goliad	7,600	7,650	Lagarto
13	Little Kentucky	Jackson	5,703	6,850	Lissie
14	Sterling	Jackson	4,844	6,503	Lissie
15	Armstrong	Jim Hogg	3,247	3,260	Reynosa
16	Weil	Jim Hogg	5,061	5,185	Reynosa
17	Yeager	Jim Hogg	3,764	3,771	Reynosa
18	North Magnolia City	Jim Wells	5,260	6,156	Lissie
19	Wilson	Jim Wells	7,348	8,211	Lissie
20	Burrell-Wilcox	Karnes	6,742	7,016	Lagarto-Oakville
21	Hobson	Karnes	4,000	4,800	Catahoula
22	Hando Creek	Karnes	6,582	8,160	Oakville-Lagarto
23	Porter	Karnes	4,120	8,015	Lagarto-Oakville
24	North Porter	Karnes	4,011	4,182	Lagarto-Oakville
25	Runge	Karnes	6,599	8,020	Oakville-Lagarto
26	Coquat	Live Oak	7,462	8,030	Oakville-Lagarto
27	Goebel[a]	Live Oak	6,970 7,082	7,090	Oakville-Lagarto
28	Violet	Nueces	7,202	8,176	Beaumont
29	Inari	Refugio	5,025	7,134	Lissie
30	North La Ward	Refugio	6,185	6,502	Lissie
31	Orenal	San Patricio	6,442	7,061	Beaumont-Lissie
32	Cameron	Starr	4,130	5,005	Reynosa
33	Lockhart	Starr	3,617	3,626	Catahoula
34	Ross	Starr	2,848	4,004	Reynosa
35	Hartman	Zapata	1,941	2,312	Frio

[a] Dual completed.

TABLE 3.—*Important Extensions Drilled in South Texas in* 1943

	Field	County	Mo. Disc.	Avg. Pay Depth	Sand Thickness, Ft.	Age Sand	Type Discovery
1	Cadena	Duval	Dec.	*x*	*x*	*x*	Gas
2	East	Jim Hogg	Feb.	4,730	*x*	Pettus	Oil
3	Imogene	Atascosa	June	7,625	20	Edwards Lime	Oil
4	Thomas Lockhart	Duval	Dec.	*x*	*x*	*x*	Oil
5	Strake	Duval	Dec.	*x*	*x*	*x*	Oil
6	North Sun	Starr	June	8,064	2(?)	Frio	Oil, gas, S.W.
7	Taft	San Pat.	Dec.	*x*	*x*	*x*	Oil
8	Wade City	Jim Wells	Jan.	4,800	18 disc	Frio	Gas dist.
9	Willamar	Willacy	Aug.	7,930	7,919–7,947	Frio	Oil
10	Yorktown	DeWitt	Feb.	7,200	Shy broken 13	Wilcox	Gas dist.

allowables. It will be exceedingly difficult to maintain the present rate of production.

The past year saw the first dual oil completion for South Texas, and in many fields

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1943

	Deepest Zone Penetrated	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.	Gas, Cu. Ft.		Casing	Tubing	
1	Vicksburg	Pure Oil Co.	x	1,400,000	5/32	sealed	1,875	
2	Wilcox	Machank Oil Co.	48	3,645,000	¼	2,455	2,325	
3	Pettus	H. B. Zachry Co.	77	x	3/16	550	135	
4	Wilcox	Dirks & Coquat	124	3,650,000	¼	2,200	2,200	
5	Vicksburg	W. E. Rowe	70 Shut-in	 x	5/32	1,700	1,300	60% water
6	Frio	Humble O. & R. Co.	178	570,000	3/16	sealed	710	S. and P. 2,400 lb.
7	Pettus	Stanolind O. & G.	16	x	pump	x	x	
8	Yegua	H. J. Porter	10	x		x	x	Flowing by heads
9	Yegua	G. W. Strake	5 bbl.	10,000,000	3/16 ⅛	1,125 1,125	Sealed 1,250	
10	Wilcox	Continental Oil & Atlantic		19,000,000	2	2,200	2,500	
11	Vicksburg	Fred W. Shield	156	120,000	5/32	1,500	1,300	
12	Wilcox	Continental Oil Co.	232	120,000	5/32	1,460	1,075	
13	Vicksburg	W. L. Pickens	132	125,000	7/64	980	765	
14	Wilcox	Boyle Sterling O. & R. Co.	x	15,000,000	x	x	x	
15	Jackson	The Texas Company	82	10,000	5/16	350	80	
16	Jackson	Sun Oil Co.	99	80,000	3/16	1,225	535	
17	Pettus	M. L. Massingill	114	x	¼	350	25	
18	Vicksburg	Humble O. & R. Co.	121	46,000	½	sealed	60	
19	Frio-Vicksburg	Sam Wilson	x	100,000,000	open flow test		x	
20	Wilcox	American-Liberty	16.5	5,300,000	5/6	x	2,250	
21	Wilcox	Seaboard Oil Co.	93	76,000	⅛	1,550	950	
22	Wilcox	Philips Petr. Co.	174	180,000	½	835	250	
23	Wilcox	Transwestern Oil Co.	38	9,000,000	13/64	1,625	1,525	
24	Pettus	Cox and Hamon	118	50,000	5/32	1,050	525	
25	Wilcox	Arkansas Fuel Oil Co.	132	66,000	¾	140	60	
26	Wilcox	H. Coquat	33	1,700,000	¼	1,300	1,165	
27	Wilcox	H. Coquat	 90	10,000,000	⅜ 3/16	2,100	 1,825	
28	Vicksburg	Philips	6.5	186,000	⅛	2,715	2,100	
29	Frio	P. R. Rutherford	x	36,000,000	open flow	x	x	
30	Frio	P. R. Rutherford	90	3,600,000	⅛	2,310	2,200	
31	Frio	John O'Neal	52	2,320,000	3/16	sealed	2,600	
32	Frio	Continental	225	200,000	3/16	1,300	900	
33	Yegua	L. M. Lockhart	66	x	⅛	900	200	
34	Frio	Goldstein et al.	6	x	⅛	sealed	50	
35	Jackson	Texas Co.	x	2,225,000	open flow		x	S. and P. 680 lb.

TABLE 3.—(*Continned*)

	Discovery Well	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Cu. Ft.		Casing	Tubing	
1	Taylor Ref. Co. No. 1 C. P. G. de Garcia		6,200,000 plus spray dist.				1 mile W. extension to Cadena field
2	Sun No. 4-A T. T. East	90	Ratio, 650	3/16	980	175	1½ miles S. extension
3	Humble No. 1 Coward	292	Ratio, 13,500	½	Sealed	775	1½ miles S. W. extension
4	Pan American						1 mile N. extension to abandoned field
5	Stanolind No. 2 Clara Driscoll	16 oil, 24 S. W.			Pumping		2 mile N. E. extension
6	Sun No. 1 Montalvo Heirs	20 oil, 365 S. W.	Ratio, 7,135	5/32	900	450	6000 ft. S extension
7	Republic Natural No. 1 Hancock Mutual Life Ins. Co.	85		⅛	700	380	¾ mile W. extension
8	Republic No. 1 L. A. Straube		32,000,000	open			3000 ft. S. W. gas extension
9	Baldridge & King No. 1 Cavazas	395	Ratio, 711	¼	885	325	8300 ft. S. extension
10	Adams No. 1 J. E. Piefner	180 dist.	15,000,000	¾	980	1,050	4700 ft. S. E. of production

TABLE 4.—*New Sands Drilled in South Texas in* 1943

	Field	County	Month Discovered	Average Depth, Ft.	Pay Sand Thickness, Ft.	Age of Sand	Type Discovered
1	Bentonville (Richard King)	Nueces	Jan.	5,570	25	Frio	Oil
2	Burnell	Karnes	Feb.	6,740	8	Carrizo-Wilcox	Gas dist.
3	Driscoll "B"	Duval	Apr.	2,900	4	First Driscoll	Oil
4	Odem	San Pat	Sept.	6,700	20	Frio	Oil
5	Robstown	Nueces	Nov.	7,140	3 max.	Frio	Oil
6	South Sinton	San Pat.	Nov.	3,270	25	Catahoula	Gas
7	St. Charles	Aransas	Oct.	x	x	Frio	Dist.
8	Seeligson	Jim Wells	Feb.	5,670	x	Frio	Oil
9	Stratton	Kleberg	May	6,145	8	Frio	Oil
10	North Sun	Nueces	Nov.	x	x	Frio	Gas dist.
11	Woodsboro	Refugio	Aug.	5,520	6	Frio	Oil

	Discovery Well	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U.S. Bbl.	Gas, Cu. Ft.		Casing	Tubing	
1	Sun Oil No. 1 E. M. Brownlee	181	Ratio, 661	⅛	200	900	
2	American Liberty No. 1 W. Otto Von Roeder	16½ dist. per million cu. ft.	5,300,000	5/16			Wilcox production
3	Continental No. 15 B. Driscoll	120		¼ set	2,450	2,250	
4	Seaboard Oil No. C7-A Welder Unit	186 Oct. 45	Ratio, 620	⅛	Sealed	1,125	
5	Sam E. Wilson No. 2 E. W. Naumann	81	Ratio, 1,250	⅛	1,800	600	New deep sand
6	Seaboard-Tide Water No. 1 J. D. Hollon		S.I.		1,475 S.I.	1,400 S.I.	
7	Continental No. 6 St. Charles	110	Ratio, 23,215	3/16	Sealed	2,750	
8	Magnolia et al. No. 38 Seeligson	92		5/32	Sealed	500	First oil prod. from zone 18
9	Chicago Corp. No. 52 Wardner	157		5/32		1,410	"Clyde sand" well, dual completion
10	Sun Oil Co. No. 3 D. Laurel	20	Ratio, 21,950	3/16	480	950	New deep sand discovery
11	Southern Minerals No. 5 R. H. Wood	162	Ratio, 671	⅛	1,220	910	

that have multiple sands it is now common practice to dually complete the wells. Dual completions may be sources of trouble and when either zone or both zones begin to produce water or increase in gas-oil ratio.

TABLE 5.—*Wells Drilled in South Texas in* 1942 *and* 1943

Year	Total Wells Drilled	Oil	Gas	Dry
1942	1,077	622	41	414
1943	982	495	63	424
	WILDCAT WELLS			
1942	297	26	2	269
1943	330	30	5	295

With the increase in allowables for all fields, the number of workovers has increased, and this work will increase as it becomes more difficult for our wells to maintain their present rate of production.

GENERAL

During the latter part of 1943, there was an increase in the number of wells being drilled. If this is continued it should be reflected in a greater number of new oil fields and extensions of old fields being discovered in 1944. New discoveries in South Texas will probably reflect the general trend throughout the United States, as we can expect more discoveries, but the reserves in each new discovery may be smaller than in previous years.

Oil and Gas Development in South Central Texas in 1943

By William H. Spice, Jr.,* Member A.I.M.E.

For the year 1943, exploratory drilling in South Central Texas continued on the sharp decline that started during 1942. Of the 30 counties comprising this district, as now revised to include the same area as is covered by District No. 1, Oil and Gas Division, Railroad Commission of Texas, 15 counties are producing oil or gas. Only 29 exploratory wells were drilled during 1943, as compared with 51 exploratory wells in 1942, or a decrease of over 40 per cent.

One new oil field and one new gas field were discovered during the year and a new horizon was discovered in an existing oil field. This compares with two new oil fields and an extension to an existing gas field in 1942.

The one new oil field, South Washburn, in southeastern La Salle County, was discovered by Quintana Petroleum Corporation's No. 1-D South Texas Syndicate in April 1943, flowing 4 bbl. per day, 48° A.P.I. gravity oil with an estimated 4 million cubic feet of gas from Wilcox sand at 6030 ft. This well is the result of an extensive seismograph survey of the area. It is about 4½ miles southwest of the same company's Green Branch field and by the end of the year one dry hole had been drilled to the southwest of this discovery.

The one new gas field, which was not named, was located in eastern McMullen County by Edwin M. Jones' No. 102 Ezzell, in November 1943, for an estimated 8 million cubic feet of gas from shallow Jackson sand at 1222 ft. No additional wells have been drilled in this area, which may also be considered as an extension to the South Calliham field.

The one new producing horizon was discovered in the South Campana field in southeastern McMullen County, by Argo Oil Corporation's No. 2-G Edrington, in January 1943, flowing 55 bbl. per day, 21° A.P.I. gravity oil with 40 per cent water from Government wells sand at 2609 feet.

None of these discoveries were of major importance and subsequent development in these new areas has proved to be disappointing.

Production for the district during 1943 totaled approximately 6,985,000 bbl. from about 3430 producing wells. This is an increase in production of about 5 per cent over 1942, but a decrease in producing wells of about 10 per cent under the number of wells producing in 1942 for the same district. Average production per well was 5.4 bbl. during 1943 as against 4.8 bbl. during 1942. Approximately 5,320,000 bbl. of this total production, or 76 per cent, was produced by the four Edwards lime fields, Luling, Branyon, Salt Flat, and Darst Creek, which are from 22 to 14 years old. The remaining production came from the 43 other active oil fields in the district.

Drilling in the proven fields maintained approximately the same level as for 1942, with a total of 36 wells drilled. Of these operations, 21 were oil wells, one was a gas well and 14 were dry holes. This is a slightly better proportion of producers than for 1942. Washburn field had the greatest number of new producing wells drilled during the year, with a total of 10.

Manuscript received at the office of the Institute April 24, 1944.

* Consulting Geologist, San Antonio, Texas.

TABLE 1.—*Oil and Gas Production in South Central Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c]		Gas Production, Millions Cu. Ft.[e]		Number of Oil and/or Gas Wells[f]		
									1943	
				To End of 1943	During 1943	To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned
1	Alta Vista,[1] *Bexar*	1912	300	125,480	0			41	0	21
2	Bee Creek, *Caldwell*	1940	320	266,199	17,142			33	1	7
3	Branyon, *Caldwell*	1930	900	3,080,782	114,026			185	0	29
4	Buchanan, *Caldwell*	1928	250	474,772	21,446			41	0	0
5	Burdette Wells,[2] *Caldwell*	1936	200	60,803	1,076			12	0	0
6	Byersville,[3] *Williamson*	1933	370	584,459	12,666			41	0	0
7	Calliham,[4] *McMullen*	1918	500	1,080,091	38,627			142	0	0
8	Campana,[5] *McMullen*	1938	10	831	0			1	0	1
9	South Campana, *McMullen*	1941	180	124,927	64,238			15	1	0
10	Carrizo, *Dimmit*	1941	20	6,391	332			1	0	0
11	Carroll,[5] *Bastrop*	1932	100	101,547	0			9	0	0
12	Cedar Creek, *Bastrop*	1932	100	307,089	10,117			13	0	0
13	Chapman, *Williamson*	1928	450	4,459,270	47,777			70	0	0
14	Chicon Lake, *Medina*	1929	450	108,752	13,616			83	0	2
15	Crowther,[6] *McMullen*	1915	80	25,000	0			23	0	0
16	Dale,[7] *Caldwell*	1927	840	1,656,705	48,985			72	2	1
17	Darst Creek, *Guadalupe*	1928	1,920	55,415,634	2,732,990			362	0	0
18	Darst Creek Ext.,[8] *Guadalupe*	1935	200	391,540	5,413			11	0	3
19	Day,[9] *Guadalupe*	1940	20	0	0			2	0	0
20	Dunlap, *Caldwell*	1930	120	379,897	11,451			14	0	0
21	Dunlay,[9] *Medina*	1938	30	1,988	0			1	0	0
22	Eckert, *Bexar*	1927	850	956,382	21,490			121	0	0
23	Elgin,[5] *Bastrop*	1941	10	3,565	0			1	0	0
24	Elm Creek,[10] *Guadalupe*	1939	400	42,570	8,649			47	0	0
25	Ezzell, *McMullen, Live Oak*	1937	1,500	3,033,010	243,304			151	0	0
26	Gas Ridge, *Bexar*	1912	150	114,282	12,340			128	0	0
27	Green Branch, *McMullen*	1942	50	855	855	71	71	1	1	0
28	Hilbig, *Bastrop*	1932	260	1,831,392	129,633			14	0	1
29	Imogene, *Atascosa*	1942	160	30,208	29,373			4	3	0
30	Jacob,[11] *McMullen*	1926	1,290	1,739,378	84,398			129	0	0
31	Jones,[5] *Bexar*	1921	20	2,888	0			3	0	3
32	Kimbro, *Travis*	1935	40	5,271	1,097			4	0	0
33	La Coste,[12] *Bexar*	1939	40	4,524	412	*x*	29	5	0	0
34	Larremore,[1] *Caldwell*	1927	80	359,398	4,490			13	0	12
35	Lentz, *Bastrop*	1941	60	25,569	8,443			3	0	0
36	Loma Alta, *McMullen*	1935	80	178,344	15,752			4	0	0

[b] Footnotes to column heads and explanation of symbols are given on page 270.
[1] Abandoned 1943.
[2] N.E. Luling.
[3] Includes Mathews and Noack.
[4] Includes S. Calliham.
[5] Abandoned 1942.
[6] Abandoned, date unknown.
[7] Included with W. Dale, N. Dale (Bateman).
[8] Clark.
[9] Abandoned 1940.
[10] Lavernia.
[11] Includes N. Jacob.
[12] Fairfield.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
1	0	0		*x*			35.0	0.3	Navarro sands, CreU	S	15–20	220	20	F	Trinity sand	4,535
2	0	25		*x*			39	*x*	Dale lime, Serpentine, CreU	LP	Por	2,050	*x*	Intn	Austin chalk	2,250
3		138		*x*			37	0.8	Austin chalk, Edw. lime, CreU	L	Por	1,816	*x*	F	Edwards lime	2,450
4	0	23		*x*			32	0.2	Serpentine, CreU	P	12	1,750	*x*	Intn	Edwards lime	2,483
5	0	2		200			36	0.8	Edwards lime, CreL	L	Crev.	2,210	15	F	Edwards lime	2,420
6	0	41		*x*		G	37	0.2	Serpentine, CreU	P	20	850	*x*	Intn	Edwards lime	2,000
7	0	59		*x*			20 20.6 Gas	*x*	Mirando Govt. Wells, Pettus, Loma Novio, Eoc	S	Por	848 1,030 1,221	15 10 10	M F L	Carrizo	5,301
8	0	0		*x*			24	*x*	Government Wells, Eoc.	S	Por	2,492	20	MF	Pettus	3.102
9	12	2		*x*			22.8	*x*	Cole Govt. Wells, Pettus, Eoc	S	Por	1,864 2,554 3,012	3*x* 10 12	MF	Cook Mountain	4,486
10	1	0		*x*			30	*x*	Navarro sd., CreU	S	12	2,300	78	Intn	Edwards lime	2,919
11	0	0		*x*			36	0	Serpentine, CreU	P	12	2,300	78	Intn	Edwards lime	2,919
12	0	7		100			35	0.2	Serpentine, CreU	P	15–20	1,650	50	Intn	Edwards lime	2,300
13	0	70		400			36	0.2	Serpentine, CreU	P	20	1,750	20	Intn	Edwards lime	3,226
14	0	74		*x*			21	0.1	Navarro sands, CreU	S	15	260	20	D	Edwards lime	1,725
15	0	0		*x*			18	*x*	Diboll, Eoc	S	Por	500	10	ML	Cook Mountain	2,000
16	0	52		150			37	0.2	Dale lime, Serpentine, CreU	LP	15	1,915	30	Intn	Edwards lime	2,661
17	6	340		350			36	0.8	Edwards lime, CreL	L	Por	2,650	30	F	Travis Peak	5,509
18	0	2		200			33.6	0.5	Austin Chalk, CreU	C	5–25	2,375	100	F	Edwards lime	3,200
19	0	0		*x*			36	*x*	Austin Chalk—Buda lime, CreU	CL	Por	2,377	*y*	F	Edwards lime	2,830
20	0	7		400			36	0.6	Austin Chalk, CreU	C	Crev.	2,375	15	F	Edwards lime	2,420
21	0	0		*x*			21	*x*	Serpentine, CreU	P	*y*	542	*x*	Intn	Austin Chalk	851
22	0	101		*x*			34	0.3	Navarro sands, CreU	S	16	620	10	F	Edwards lime	1,590
23	0	0		*x*			36	*x*	Austin chalk, CreU	C	Crev.	2,820	20	F	Edwards lime	3,352
24	0	29		*x*			40–42	*x*	Navarro sands, CreU	S-Sh	Por	700	*x*	T	Navarro	800
25	1	126		*x*		G	20	*x*	Loma Novio, Eoc	S	Por	1,490	11	ML	Cook Mountain	3,180
26	0	64		*x*			22	0.4	Navarro sands, CreU	S	15–20	230	15	A	Travis Peak	3,460
27	1	0		*x*			28.2 Gas	*x*	Reklaw, Eoc Wilcox, Eoc	S S	Por Por	3,935 5,720	*x* 6	F	Navarro	7,623
28	1	11	1	1,240		P	37	0.2	Serpentine, CreU	P	12	2,450	50	Intn	Edwards lime	3,250
29	1	3		*x*			38.7	*x*	Edwards lime, CreL	L	Por	7,570	2	*x*	Edwards lime	7,648
30	0	71		*x*			Gas 21.5 20.5	*x*	Mirando Pettus, Eoc Yegua	S	Por	1,050	8 7 8	ML	Mt. Selman	3,171
31	0	0		*x*			*x*	*x*	Navarro sands, CreU	S-Sh	Por	600	*x*	T	Edwards lime	2,008
32	0	4		*x*			36.5	*x*	Serpentine, CreU	P	Por	660	*x*	Intn	Edwards lime	1,280
33	0	1		*x*			31	*x*	Anachacho lime, CreU	L	Por	1,150	*x*	N	Austin chalk	1,227
34	0	0	3	*x*			23	0.6	Edwards lime, CreL	L	30	1,285	35	F	Travis Peak	3,360
35	0	3		*x*			36	*x*	Dale lime, CreU	L	Por	2,226	18	F	Austin chalk	2,453
36	0	3		*x*			21	*x*	Chernosky, Eoc	S	Por	2,195	12	MFL	Cockfield	2,766

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[c] To End of 1943	Oil Production Total, Bbl.[c] During 1943	Gas Production, Millions Cu. Ft.[e] To End of 1943	Gas Production, Millions Cu. Ft.[e] During 1943	Number of Oil and/or Gas Wells[f] Completed to End of 1943	Number of Oil and/or Gas Wells[f] 1943 Completed	Number of Oil and/or Gas Wells[f] 1943 Abandoned
37	Lone Oak,[9] *Bexar*	1934	10	4,485	0			1	0	0
38	Luling, *Caldwell, Guadalupe*	1921	2,200	80,022,808	1,649,798			606	0	42
39	Lytton Springs, *Caldwell*	1925	1,360	8,758,696	83,233			157	0	12
40	Manda,[5] *Travis*	1935	40	25,269	0			3	0	0
41	Manford, *Guadalupe*	1929	40	421,879	6,567			1	0	0
42	Minerva-Rockdale, *Milan*	1921	4,250	3,810,624	66,105			423	0	13
43	Munson, *McMullen*	1938	150	201,544	15,601			17	0	1
44	Nash Creek,[13] *Guadalupe*	1936	10	46,535	0			1	0	0
45	Pearsall, *Frio*	1933	880	1,936,281	255,904			37	2	1
46	Philtop,[5] *Bexar*	1938	40	8,171	0			8	0	0
47	Riddle, *Bastrop*	1938	50	94,017	8,601			7	0	0
48	Salt Flat, *Caldwell*	1928	1,300	44,341,256	826,431			298	0	4
49	San Jose,[14] *McMullen*	1938	10	450	0			2	0	0
50	Somerset, *Atascosa, Bexar*	1912	11,390	11,151,086	87,028			915	0	249
51	Southton-Yturria, *Bexar*	1921	650	701,888	14,243			103	0	0
52	Spiller, *Guadalupe*	1938	30	23,122	2,319			6	0	1
53	Taylor-Ina, *Medina*	1922	380	160,529	1,014			17	0	0
54	Tenney Creek, *Caldwell*	1940	150	299,574	90,017			25	1	0
55	Thrall, *Williamson*	1914	475	2,516,438	16,662			27	0	0
56	Von Ormy, *Bexar*	1933	650	309,666	17,366			109	1	1
57	Walnut Creek, *Caldwell*	1938	50	8,974	971			3	0	0
58	Washburn,[15] *LaSalle*	1940	420	218,890	115,470			25	10	0
59	Yost, *Bastrop*	1928	120	927,650	5,643			6	0	0
60	Zoboroski, *Guadalupe*	1935	180	259,772	14,906			14	0	0
	GAS ONLY									
61	Adams, *Medina*	1926	2,000	0	0	x	x	58	0	0
62	Chittim, *Maverick*	1929	100	77,701	7,359	x	1,534	20	0	0
63	Pendencia Creek, *Dimmit*	1941	1,320			x	x	3	0	0
64	Rhode, *McMullen*	1936	1,200			x	x	11	0	0
65	Wentz, *McMullen*	1932	80			x	x	3	0	0
66	Totals		41,831	233,307,097	6,985,376		1,634x	4,706	22	404

[13] Abandoned 1941.
[14] Abandoned 1939.
[15] Includes S. Washburn.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
37	0	0		*x*			33.4	*x*	Navarro-Taylor, CreU	S	Por	1,480	18	F	Edwards lime	2,250
38		538		1,500			27	0.9	Edwards lime, CreL	L	25	2,100	50	F	Schist	7,859
39	0	134		1,250			31.5	0.4	Serpentine, CreU	P	12	1,535	*x*	Intn	Edwards lime	2,050
40	0	0		*x*			34	0.4	Serpentine, CreU	P	15–25	720	*x*	Intn	Taylor marl	850
41	0	1		1,250			37	0.9	Austin chalk, CreU	C	35	2,260	30	F	Edwards lime	2,800
42	0	406		*x*			38	0.2	Navarro sands, CreU	S-Sh	Por	600	15	T	Edwards lime	5,000
43	0	11		*x*			20.7–22.5	*x*	Mirando, Eoc	S	Por	1,200	12	ML	Pettus	1,501
44	0	0		340			27	0.8	Taylor Marl, CreU	SL	Por	2,570	30	F	Edwards lime	3,342
45	6	30		1,500			28	0.4	Navarro sands, Austin chalk, CreU	S.C.	Por	3,920 5,400	15 *x*	N	Travis Peak	10,050
46	0	0		*x*			23	*x*	Austin chalk, CreU	C	Por	1,100	*x*	F	*x*	*x*
47	0.	3		*x*			39	*x*	Austin chalk and Serpentine, CreU	CP	Por	1,667	*x*	F	Austin chalk	1,777
48	0	268		200			36	0.6	Edwards lime, CreL	L	30	2,670	25	F	Edwards lime	2,918
49	0	0		*x*			23	*x*	Cole, Eoc.	S	Por	1,147	16	ML	Yegua	2.370
50	0	457		300			36	1.4	Navarro and Taylor sands, CreU	S-Sh	22	1,200	30	TF	Travis Peak	5,311
51	0	103		*x*			32	0.5	Navarro sands, CreU	S	16	600	10	F	Glen Rose	3,850
52	0	3		*x*			38.3	*x*	Buda lime, CreL	L	Por	2,012	*y*	F	Edwards lime	2,382
53	0	9		*x*			18–19	0.4–0.7	Navarro sands, CreU	S-Sh	15–20	290 940	16 10	F T	Edwards lime	2,048
54	5	20		*x*			38	*x*	Austin chalk, Buda lime, CreU, CreL	CL	Por	2,340	60	F	Buda lime	2,705
55	0	21		400			37	0.5	Serpentine, CreU	P	25	700	75	Intn	Travis Peak	3,290
56	0	102		*x*			34	0.4	Navarro sands, CreU	S-Sh	10	506	20	F	Edwards lime	2,835
57	0	1		*x*			36	*x*	Serpentine, CreU	P	Por	1,230	100	Intn	Austin chalk	1,900
58	19	2		*x*			41	*x*	Wilcox sand, Eoc	S	Por	4,860	7	*x*	Navarro	8,300
59	0	4		400			27	0.3	Serpentine, CreU	P	15–25	1,335	100	Intn	Edwards lime	2,600
60	0	14		150			30.4	0.8	Austin chalk, CreU	C	10	2,050	75	F	Edwards lime	2,600
GAS ONLY																
61	0	0	13	*x*			0	0	Navarro and Taylor sands, CreU	S-Sh	Por	900	*x*	F	Edwards lime	2,289
62	0	0	5	*x*			42°–44°	*x*	Buda, Edwards and Glen Rose, CreL	L	Por	3,205 3,255 5,650	*x*	A	Travis Peak	7,635
63	0	0	2	*x*			0		Navarro sand, CreU	S	Por	1,084 1,885	*x*	A	Taylor	3,005
64	0	0	10	*x*					Cole, Eoc	S	Por	1,800	12	MFL	Yegua	3,534
65	0	0	0	*x*					Cole, Eoc	S	Por	370	12	ML	Yegua	1,654
66	53	3,385	37													

Imogene field had three new producers and Dale and Pearsall fields had two new producers each.

Approximately 400 wells in the district were abandoned during the year. In the Somerset field alone, 249 wells were abandoned and equipment salvaged. Production in this field dropped from a total of 140,937 bbl. in 1942 to 87,028 bbl. in 1943. In Luling field, 42 wells were abandoned; in Minerva-Rockdale field, 13 wells were abandoned, and in Lytton Springs, 12 wells were abandoned. These were all marginal wells in fields from 32 to 19 years old and reflect material and manpower shortages, together with rising operating costs. The high rate of abandonments is a serious factor, which will prevent future increases in the production rate for the district and undoubtedly will be reflected in a more rapid decrease in production during the next few years.

Exploratory work in the district was confined mainly to the areas along the Wilcox trend, with some scattered test wells along the deeper Edwards lime trend in the western part of the district. Leasing has also been most active in these areas, with additional activity directed toward areas favorable for deeper lower Cretaceous production and those with Jurassic possibilities.

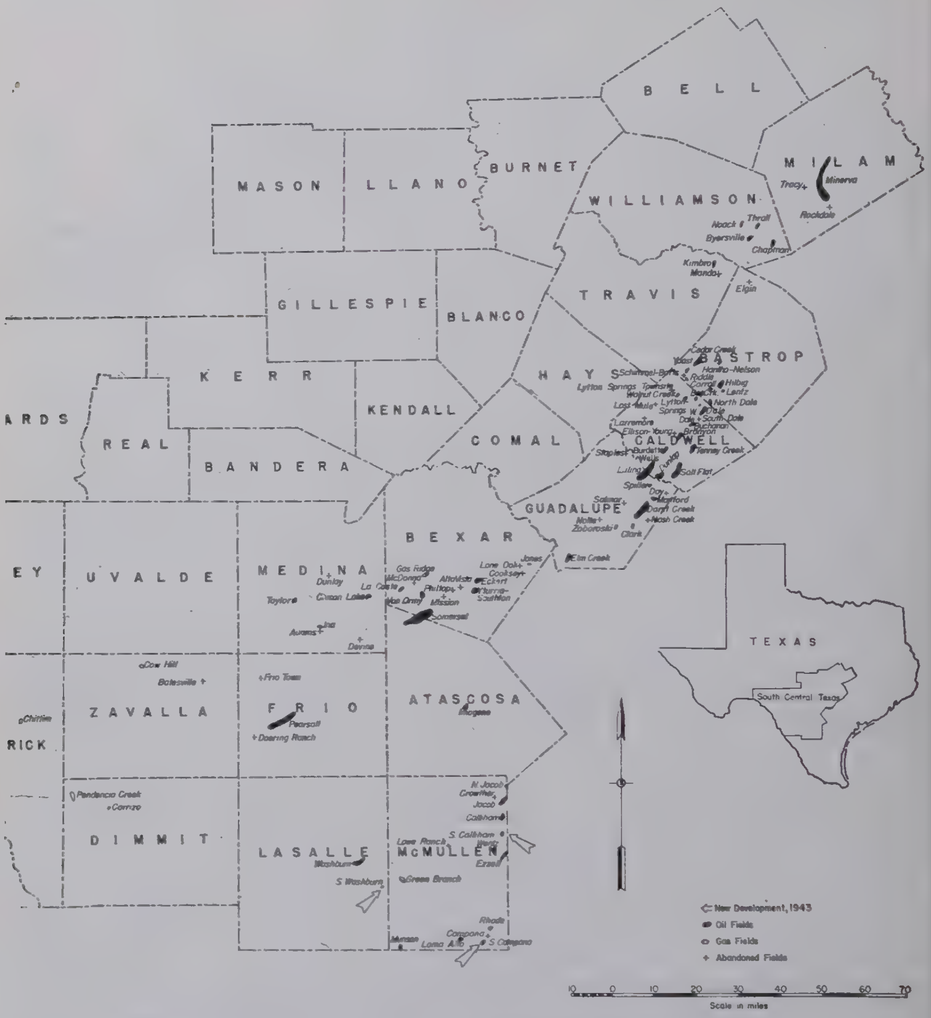

FIG. 1.—LOCATION OF OIL AND GAS FIELDS, SOUTH CENTRAL TEXAS.

ACKNOWLEDGMENT

Appreciation is expressed to the many companies and individuals who cooperated by furnishing many of the production and well data shown on Table 1.

Developments in West Texas Oil Fields during 1943

By Robert S. Dewey,* Member A.I.M.E.

As a result of drilling operations during 1943, West Texas again added sufficient new oil reserves to replace the oil produced during the year, but failed to maintain its position in currently available reserves because the deeper discoveries will require years for development. Drilling failed to provide the additional oil necessary to meet the increase in current and anticipated market demand. Although 13.3 per cent of the total footage drilled was in wildcat exploration, the ratio of oil discoveries to total wildcats was less in 1943 than in 1942, but comparable to that in 1941. Of the 732 field wells completed, 270 were at Slaughter, 55 at Wasson, 45 at Mascho and 31 at North Cowden.

As of Dec. 31, 1943, there were 361 drilling wells including 71 wildcat and 290 field wells; 19.7 per cent were wildcats. It is anticipated that the percentage of wildcats of the total wells will be higher during 1944 than in either 1942 or 1943. Tables 3 and 4 present a three-year comparison of drilling activity and illustrate the downward trend of development that has been in effect during that time.

Because of development lag in the deeper Ordovician fields, several years elapse before a sufficient number of wells is completed to give a substantial producing rate. As these new oil reserves cost more to find, and will cost more to produce on a barrel basis than the oil marketed during the year, their reserve replacement value to the industry is less in money.

Costs

While complete costs for deeper drilling are not yet available for analysis, it is evident from the data on drilling rates to comparable depths, contract prices, and general increases in costs, that the cost of drilling has risen approximately 20 per cent during the year. One representative drilling contractor estimates that the average drilling time on a 5000-ft. field well has increased nearly one third and that out-of-pocket costs have increased a dollar per foot. Three major factors contribute to this increased cost: (1) less experienced labor, (2) deterioration in mechanical equipment and expendable material, and (3) increased contract prices.

In the past, when there were more drilling rigs than wells to be drilled, some contractors would cut their drilling profit to keep their personnel and rigs working. As this practice is no longer necessary, the contract prices are adjusted upward to assure a profit. On deep and difficult drilling, contracts are let on a cost plus basis. A number of mechanical difficulties have become evident. Inferior quality of steel used in drill pipe and rock bits has added appreciably to drilling time and cost. Contractors are experiencing delay in obtaining repair work and repair parts for prime movers.

As the length of drilling time required on shallow-field wells has not increased in proportion to that on deeper wells, it seems that the medium-sized drilling rig is better adapted mechanically than the heavy one to the work imposed. One of the main deficiencies in the heavy rig equipment is inadequate pump capacity.

Drilling Mud

The increasing amount of deep drilling has emphasized the importance and relationship of good mud to efficient and suc-

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* Humble Oil and Refining Co., Houston, Texas.

TABLE 1.—*Oil and Gas Production in West Texas*

Line Number	*County,* Field	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[e]		Producing Days, 1943	Gas Production, Millions Cu. Ft.[3]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943	
										Completed	Abandoned
1	*Andrews:* Clabberhill	1943	40	3,083	3,083	92			1	1	0
2	Deep Rock	1930	500	750,798	20,595	249			13	2	0
3	Embar	1942	2,230	468,886	367,432	302	214.3	158.5	18	13	0
4	Embar Permian	1942	1,950	295,581	281,541	325	391.9	11.2	11	4	0
5	Emma	1937	1,760	1,612,552	380,561	242		162.9	69	2	1
6	East Fullerton	1943	2,400	4,040	4,040	55	3.5	3.5	1	1	0
7	Fuhrman	1930	2,000	3,543,693	304,199	242		1,188	58	1	0
8	Fullerton	1942	6,000	462,300	349,569	312	361	333	30	18	0
9	Mascho[1]	1941	5,000	191,016	138,240	245	166	120	60	45	0
10	Means	1934	7,600	6,851,774	803,074	240	6,959.7	266.5	127	3	0
11	Parker	1935	80	99,284	9,737	365[2]			2	0	0
12	Union	1943	160	8,668	8,668	74	2	2	1	1	0
13	*Andrews and Ector:* North Cowden	1930	23,000	27,907,502	4,025,443	242	–	5,664	567	31	1
14	West Andrews	1940	1,000	110,553	42,327	249			23	1	3
15	*Cochran:* Dean	1937	700	142,584	50,314	249	148.8	38	9	5	0
16	Rhodes	1941	80	7,412	2,289	249			2	1	0
17	*Cochran, Hockley and Terry:* Slaughter	1936	65,000	25,778,753	11,241,025	266	15,893.9	6,890.7	1,502	278	1
18	*Coke:* Blackwell	1942	40	5,916	2,613	249			1	0	0
19	*Concho:* Dodson	1940	20	1,185	77	365[2]			1	0	0
20	*Crane:* Dune	1938	2,200	727,174	160,653	251	430	68	28	1	0
21	Edwards	1935	120	21,459	1,186	365[2]			1	0	1
22	Ella Waddell	1940	1,000	82,731	29,929	249	32	11	5	0	0
23	McKee	1942	120	43,024	34,618	365	23	18.7	3	2	0
24	Sand Hills Ordovician { Simpson[5]	1936	80	1,560,109	531,805	246	1,418	478	2	0	0
	Ellenburger[6]	1936	1,420						31	0	0
25	Sand Hills Permian	1934	7,500	5,115,206	1,363,002	248	7,548	2,206	163	16	2
26	Sand Hills West	1943	40	2,159	2,159	184	.9	.9	1	1	0
27	Waddell	1927	3,500	4,883,035	717,955	272	2,734	528	90	0	0
28	*Crane and Ector:* Jordan	1937	5,620	7,400,382	1,562,100	249		950	239	0	0
29	*Crane and Upton:* Crane-Cowden	1926	2,160	5,547,318	145,716	365[2]			141	0	4
30	McCamey	1925	19,200	57,633,417	3,189,935	249			1,109	0	22
31	McElroy	1926	14,000	133,178,662	6,148,060	290	96,155	6,056	600	1	1
32	*Crockett:* Clara Couch	1941	400	28,289	16,351	249			10	2	1
33	Crockett	1938	1,020	450,122	90,207	249			38	1	0
34	Hoover	1941	80	7,444	1,150	249			2	0	0
35	Live Oak	1940	40	3,278	558	249			1	0	0
36	Noelke	1940	1,000	371,101	180,512	249			45	7	0
37	Olson	1940	320	27,005	16,525	249			5	2	0
38	Simpson	1938	160	5,668	252	249			1	0	0
39	Todd Deep	1940	1,160	282,294	81,013	249	167	48	14	0	0
40	World	1925	3,000	8,418,956	686,432	365			111	11	0
41	Wyatt	1932	160	40,692	5,750	249	17.9	2.5	4	0	0
42	*Crockett and Pecos:* Yates	1926	20,000	275,188,227	8,676,680	352	122,137	1,650	560	1	2
43	*Dawson:* Welch	1941	160	18,829	9,118	365			1	0	0
44	*Ector:* Foster	1936	13,000	18,061,965	2,584,784	248		1,714	583	8	0
45	Goldsmith	1934	24,000	46,578,873	7,352,982	264	99,000	16,000	998	15	0
46	Harper	1933	4,000	8,479,808	507,381	246		1,044	184	0	0
47	Johnson	1935	7,520	2,671,974	810,378	248		564	126	1	0
48	North Cowden Deep	1939	400	144,598	25,951	214		18.8	5	0	0
49	North Goldsmith	1936	640	130,860	27,587	248	1,267	187	12	0	0
50	Penwell	1930	6,200	24,207,121	919,935	244	32,559	1,591	176	1	3
51	South Cowden	1933	4,530	3,613,276	825,980	235		499	124	6	0
52	*Gaines:* Cedar Lake	1939	3,000	1,028,810	452,662	249	161	74	54	3	1
53	Robertson	1942	160	17,065	13,567	360	7	5.5	1	0	0
54	Russell	1943	640	39,425	39,425	322	13.2	13.2	2	2	0

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[b] Footnotes to column heads and explanation of symbols are given on page 270.

[1] Includes West Fuhrman.

[2] All wells in field marginal—no shut in days—each well permitted maximum production daily.

[3] Gas production estimated from gas-oil ratio test made annually—in many cases the gas volume not very accurate.

[5] Two separate areas. [6] Three separate areas.

TABLE 1.—(*Continued*)

	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.			Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
Line Number	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943	Secondary Recovery[h]	Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[f]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
1	0	1	0				33		Holt, Per	LS	P	5,464	86		Clear Fork	7,500
2	2	10	0	1,800			28		San Andres, Per	D	P	4,288	20	A	San Andres	4,902
3	18	0	0	3,271			47	0.2	Ellenburger, Ord	D	2.39	7,835	223	A	Pre-Cambrian	8,015
4	11	0	0	2,341	1,950		43	2.1	Clear Fork, Per	D	6.1	6,200	100	A	Pre-Cambrian	8,015
5	0	68	0	1,500			34		San Andres, Per	D	P	4,190	25	A	San Andres	4,541
6	1	0	0	1,870			42	0.8	Wichita, Per	DL	11.1	6,900	304	A	Wichita	7,381
7	40	16	1	1,800			28	4.2	San Andres, Per	D	P	4,248	25	A	San Andres	4,614
8	29	1	1	2,925			43	0.5	Wichita, Per	D	P	7,045		A	Wolfcamp	8,005
9	32	28	0				32		San Andres, Per	D	P	4,440	20	A	Clear Fork	7,626
10	41[4]	69	2	1,900	1,485		30	2.4	San Andres, Per	D	P	4,475	25	A	San Andres	5,227
11	0	2	0				29		San Andres, Per	D	15	4,625	5	MC	San Andres	4,806
12	1	0	0	2,315	2,315		44	0.5	Clear Fork-Wichita, Per	D	P	6,900	120	A	Wichita	7,459
13	445	118	1	1,740	1,215	G	32	1.7	Grayburg, Per	DS	10.2	4,000	65	A	Clear Fork (?)	5,200
14	14	5	2				36		San Andres, Per	D	7	4,300	25	A	Ellenburger	8,368
15	5	4	0		1,125		29		San Andres, Per	D	P	4,900	12		Clear Fork	6,621
16	0	2	0				29		San Andres, Per	D	P	5,050	41	MC	San Andres	5,150
17	1,397	102	1	1,700	1,565		32	1.9	San Andres, Per	D	P	4,950	32	MC	Clear Fork	7,000
18	0	1	0				41		Cisco, Pen	L	P	3,821	7		Cisco	3,828
19	0	1	0													
20	7	20	0				34	1.5	Grayburg, Per	DL	Poor	3,150	15	A	San Andres	3,795
21	0	1	0						Grayburg, Per	D	P	3,315		A	San Andres	3,695
22	1	4	0	1,375	1,000		35		Grayburg, Per	D	P	3,250	20	A	San Andres	3,734
23	1	2	0	2,681			43	0.14	"McKee" Simpson, Ord	S	Fair	6,125	8	A	Ellenburger	7,204
24	2	0	0	2,618			37		Simpson, Ord	S	P	5,550	20	AF	Pre-Cambrian	7,158
	29	2	0				44		Ellenburger, Ord	D	Frac. Cav	5,900	20	AF	Pre-Cambrian	7,158
25	136	20	1	2,125	1,447		35		Wichita, Per	D	P	4,250	40	A	Pre-Cambrian	7,158
26	0	1	0	484	484				Holt, Per	D	P	3,800	15		Ellenburger	7,777
27	73	12	3	1,550			36	2.1	San Andres, Per	D	P	3,450	20	A	Clear Fork	3,622
28	163	61	0	1,570	1,000		32	2.1	San Andres, Per	D	P	3,500	20	A	San Andres	4,038
29	0	96	0				28	2.4	Grayburg, Per	D	10	2,250	10	A	San Andres	2,750
30	0	830	0				28	2.2	Grayburg, Per	DL	P	2,100	30	A	Ellenburger	8,358
31	72	523	0	750			30	2.4	Grayburg, Per	D	Cav	2,800	40	A	Ellenburger	12,787
32	2	6	1				26		San Andres, Per	D	P	1,882	20	A	San Andres	2,166
33	7	31	0				31	1.7	Grayburg, Per	DS	P	1,330	7	A	San Andres	1,635
34	0	2	0				26		Queen, Per	S	P	1,425	10	N	San Andres	2,173
35	0	1	0				30		San Andres, Per	D	P	2,012	10		San Andres	2,150
36	34	3	1				32		Seven Rivers, Per	S	P	1,100		NC	San Andres	2,039
37	0	5	0				25		San Andres, Per	D	P	2,202	15	A	San Andres	2,371
38	0	1	0						Grayburg, Per	D	P	1,885	10	N	Grayburg	1,970
39	14	0	0	2,600	2,560		42		Strawn, Pen	L	P	5,725	100	A	Ellenburger	7,143
40	0	89	0				29	0.7	Grayburg, Per	D	P	2,415	13	A	San Andres	3,695
41	1	0	0	555	271		23	0.7	San Andres, Per	D	10	1,217	5	A	Ellenburger	7,010
42	554	42	0	700	521		30	1.6	San Andres, Per	D	P	1,310	100	A	Ellenburger	9,114
43	0	1	0				33		San Andres, Per	D	P	4,918		A	San Andres	4,986
44	265	315	0	1,740	1,047		35	1.1	Grayburg, Per	DS	11	4,100	42	A	Holt	5,500
45	937	54	7	1,675	1,265		36	1.9	San Andres, Per	DL	10–15	4,180	65	A	San Andres	4,557
46	22	162	0				37	1.2	San Andres, Per	D	P	4,000	20	MC	San Andres	4,518
47	77	49	0				36		Grayburg, Per	D	P	4,125	25	A	San Andres	4,610
48	3	2	0	1,300			31	1.0	Clear Fork, Per	L	11	5,100	15	A	Clear Fork	5,200
49	2	8	1		913		36	2.0	San Andres, Per	DL	P	4,315	18	A	Clear Fork	6,499
50	72	98	1	1,375			35	2.6	San Andres, Per	D	P	3,550	30	A	San Andres	4,002
51	80	44	0	1,740	1,050		34	1.7	Grayburg, Per	DS	11	4,000	42	A	Holt	5,500
52	0	53	0	1,954	1,200		33	2.1	San Andres, Per	D	14.3	4,800	25	A	Strawn-Bend	11,954
53	0	1	0	2,137			26		San Angelo, Per	D	P	5,910	42	A	Tubb-Clear Fork	7,686
54	1	1	0	2,420	1,160		29	1.4	Clear Fork, Per	D	P	7,480	20	A	Clear Fork	7,770

[4] 15 wells shut in under transfer of allowable plan.

TABLE 1.—(*Continued*)

Line Number	*County*, Field	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[e]		Producing Days, 1943	Gas Production, Millions Cu. Ft.[3]		Number of Oil and/or Gas Wells[f]		
										1943	
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	Completed	Abandoned
55	Seminole	1937	12,500	8,197,485	2,840,039	249	6,869.9	2,229.4	304	12	0
56	Wasson Deep	1940	160	54,782	19,013	249	32.4	11.9	1	0	0
57	Wasson "72"	1941	160	49,828	14,932	249	21.5	5.6	1	0	0
58	*Gaines and Yoakum:* Wasson	1936	55,000	54,948,527	12,386,516	228	58,160.5	13,241.2	1,453	45	0
59	*Garza:* Garza	1935	200	128,990	7,014	249			17	0	0
60	*Glasscock and Howard:* Howard-Glasscock	1926	13,500	109,112,215	4,831,906	365			967	5	
61	1400-foot pay	1927	3,000						203	0	
62	1800-foot pay	1926	3,000						200	0	
63	2200-foot pay	1929	6,000						267	0	
64	2500-foot pay	1928	2,000						83	5	
65	3000-foot pay	1928	4,000						214	0	
66	*Howard:* Iatan-North	1943	80	7,814	7,814	129			1	1	0
67	Moore	1937	640	111,373	16,314	365[2]			8	1	0
68	Snyder	1935	1,740	2,552,569	227,947	365			101	1	0
69	Vincent	1943	40	4,574	4,574	193	2.3	2.3	1	1	0
70	*Howard and Mitchell:* Iatan-East Howard	1926	7,300	17,720,816	1,331,158	365			325	12	0
71	*Irion:* Irion	1929	340	140,815	4	365			17	0	0
72	*Kimble:* Bolt	1939	40	2,606	522	249			2	0	0
73	*Loving:* Mason	1937	350	550,882	54,832	312		47	10	0	0
74	Wheat	1925	4,060	9,207,885	296,245	249			116	0	0
75	*Lubbock:* Lubbock	1941	40	5,015	1,467	249			1	0	0
76	*Mitchell:* Westbrook	1921	4,300	9,629,731	224,044	312			156	12	0
77	*Pecos:* Abell	1940	4,000	1,886,896	954,706	230		1,020	89	5	1
78	McKee Sand	1940	2,845	(1,535,491	765,158)[9]				62	2	0
79	Simpson Dolomite	1943	40						1	1	0
80	Waddell Sand	1941	500	(125,327	54,893)[9]				14	0	0
81	Ellenburger	1941	615	(219,803	150,471)[9]				12	2	1
82	Abell Permian	1941	920	185,712	93,090	218		55	25	4	3
83	2300-foot pay	1941	320						9	3	1
84	3200-foot pay	1941	40						2	0	1
85	3350-foot pay	1941	40						1	0	1
86	3800-foot pay	1941	240						6	1	0
87	3900-foot pay	1941	280						7	0	0
88	Apco 1600	1943	40	565	565	30	0.25	0.25	1	1	0
89	Apco-Warner	1939	1,600	584,100	319,601	249		305	38	17	1
90	Chancellor	1942	80	39,464	23,371	249		28	2	0	0
91	Fromme	1939	320	110,835	16,744	249			11	0	3
92	Heiner	1941	80	17,039	11,087	249		40	2	1	0
93	Jamison and Pollard	1941	40	70,093	21,646	365		37	1	0	0
94	Lehn	1939	1,200	453,286	71,338	249		89	54	4	1
95	Masterson	1929	240	1,019,993	46,482	312		18	24	0	0
96	Masterson 3500	1943	40	12,674	12,674	262			1	1	0
97	Netterville	1934	800	408,849	20,442	249			22	0	3
98	Pecos Valley-Low Gravity	1928	2,160	1,108,634	93,279	249			78	0	3
99	Richards	1929	160	30,703	532	365[2]			3	0	0
100	Shearer	1938	480	1,368,408	157,097	249		113	48	0	0
101	Taylor Link	1929	2,500	8,248,663	583,423	365	2,755	24.5	144	13	3
102	Toborg	1928	1,320	7,881,103	471,850	284	945	4.5	260	7	3
103	Walker	1940	1,760	748,061	341,857	249		162	72	12	0
104	Wentz	1941	640	46,162	22,496	249	81.5	28	2	0	0
105	White and Baker	1935	1,320	370,035	117,885	249	223	140	33	11	0
106	White and Baker lime	1943	300	1,859	1,859	88			1	1	0
107	Yates sand	1933	700	544,194	38,646	249			10	0	0
108	*Pecos and Ward:* Payton	1937	2,000	3,170,228	297,623	249		285	142	1	0
109	Pecos Valley high gravity	1928	1,300	1,809,581	144,920	249			103	1	2
110	*Reagan:* Barnhart	1941	5,000	357,075	239,601	249	643	431	25	14	0
111	Big Lake	1923	3,300			365			308	0	0
112	2400-foot pay	1923	300	70,803,664	1,191,219				21	0	0
113	3000-foot pay	1923	3,000						261	0	12
114	4300-foot pay	1942	40						1	0	0

[8] No production reported from the Bean, Carter, Grassroots, Melvin, Stinnett and Anthony fields.

[9] Production estimated.

TABLE 1.—(*Continued*)

	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.			Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil															
Line Number	Flowing	Artificial Lift	Gas	Initial	Avg./End 1943	Secondary Recovery[h]	Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
55	298	6	0	2,000	1,917		35	1.8	San Andres, Per	D	P	5,000	90	A	Wolf Camp	9,312
56	1	0	0				32	1.4	Clear Fork, Per	D	P	6,210				11,108
57	1	0	0				35	1.0	Tubb-Clear Fork, Per	D	P	7,055				11,108
58	1,349	102	0	1,800	1,594		34	1.6	San Andres, Per	D	P	4,900	50	AM		11,108
59	0	4	0						San Andres, Per	DL	P	2,800	20	A	San Andres	2,940
60	0	830	0													
61	0	178	0				32	1.0	Yates, Per	S	P	1,280	20	A	Ellenburger	10,906
62	0	143	0				32	0.8	Seven Rivers (?), Per	S	20	1,650	20	A	Ellenburger	10,906
63	0	237	0				30	1.6	Grayburg (?), Per	DL	P	2,150	30	A	Ellenburger	10,906
64	0	72	0				30	0.9	San Andres, Per	DL	P	2,400	30	A	Ellenburger	10,906
65	0	200	0				27	3.4	San Andres-Clear Fork, Per	DL & S	P	2,900	20	A	Ellenburger	10,906
66	1	0	0						Clear Fork, Per	D	P	2,450		A	Wichita (?)	4,220
67	0	8	0				28	2.3	Grayburg, Per	DL	P	3,197	3		Grayburg	3,205
68	0	100	0				30	1.7	San Angelo, Per	DL	P	2,650	50	A	Clear Fork	3,750
69	0	1	0				27		Clear Fork, Per	D	P	4,040			Clear Fork	4,096
70	26	296	0				27	1.4	Clear Fork, Per	D	P	2,450	50	A	Wichita (?)	4,220
71	0	1	0				38		San Angelo, Per	S	P	1,370	10	ML	Wichita (?)	3,972
72	1	1	0				27		Strawn, Pen	S	P	1,415	10	AF	Ellenburger	2,074
73	6	3	0				39	0.1	Delaware, Per	S	P	3,930	10	T	Delaware	4,165
74	38	49	0				38	0.2	Delaware, Per	S	P	4,290	7	MC	Delaware	5,083
75	0	1	0				28		Clear Fork, Per	D	P	4,870			Clear Fork	5,002
76	0	111	0				23	3.9	Clear Fork, Per	D	P	2,800	50	MC	Pennsylvanian	7,488
77	78	4	3												Ellenburger	6,483
78	62	0	0	2,485	2,045		43		McKee-Simpson, Ord	S	P	5,270	20	A		
79	1	0	0				42	1.5	Simpson, Ord	D	P	5,711	20	AF		
80	9	0	3	2,726	2,370		41		Waddell-Simpson, Ord	S	P	5,725	10	A		
81	6	4	0	2,768	2,669		41	4.4	Ellenburger, Ord	D	Frac.	5,800	30	AF		
82	10	12	0													
83	4	4	0	1,225	1,140		36	0.6	San Andres, Per	D	P	2,275	20	A	Pre-Cambrian	5,745
84	1	0	0	1,765	1,430		26	2.0	Lower San Andres, Per	D	P	3,210	25	A	Ellenburger	6,483
85	0	0	0	1,848	1,404		34	0.8	Upper Clear Fork, Per	D	P	3,350	20	A	Ellenburger	6,483
86	4	2	0	1,778	1,565		35	0.4	Wichita, Per	D	P	3,750	30	A	Pre-Cambrian	5,745
87	1	6	0	1,669	1,425		37	0.9	Wichita, Per	D	P	3,895	30	A	Ellenburger	6,483
88	1	0	0				35		Queen, Per	S	P	1,649	12	A	Queen	1,661
89	36	1	0				41	0.3	Ellenburger, Ord	D	Cav	4,550	20	A	Pre-Cambrian	4,526
90	1	1	0	1,915			36		Delaware, Per	S	P	5,075	5	H	Delaware	6,001
91	5	2	1				32		Queen, Per	S-D	P	1,412	15	A	San Andres	1,674
92	0	2	0				35		Ellenburger, Ord	D	P	5,382			Ellenburger	5,665
93	1	0	0				24		San Andres, Per	D	P	2,037	4		San Andres	2,550
94	14	34	0				34		Queen, Per	S	P	1,675	10	A	Grayburg	1,995
95	0	24	0				28	1.4	Queen, Per	S	P	1,200	5	M	Pre-Cambrian	4,526
96	1	0	0	1,701			22		Tubb, Per	D	Fis	3,542		A	Ellenburger	4,700
97	11	5	0				41		Yates, Per	S	P	1,300	15	A	San Andres	2,550
98	26	44	0				25	1.7	Yates, Per	S	P	1,500	15	A	Ellenburger	5,665
99	0	3	0				17		Dewey Lake, Per	S	P	1,380	10		San Andres	4,360
100	5	38	0				35		Seven Rivers, Per	S	P	1,415			Pre-Cambrian	4,526
101	25	108	0	700	55		29	1.3	Yates, Queen, San Andres, Per	D-S	P	1,580	25	A	San Andres	1,845
102	0	257	0	108	32		19	1.9	Tobarg, Cre	S	P	400	15	AL	San Andres	1,400
103	59	13	0				30	1.4	Queen, Per	S	20	1,950	25	A	San Andres	2,136
104	0	2	0	1,399	956		33		Ellenburger, Ord	D-S	P	4,300	20		Pre-Cambrian	4,493
105	27	1	5	800	750		30		Queen, Per	S	20	1,700	30	A	Lower Ordovician	9,811
106	1	0	0	750	750		29		San Andres, Per	L	P	1,704	45	A	Lower Ordovician	9,811
107	0	10	0				32	1.5	Yates, Per	S	P	900	15	AL	Ellenburger	9,114
108	14	116	0				33	1.1	Yates, Per	S	P	2,000	40	A	San Andres	3,200
109	40	59	0				38	1.1	Yates, Per	S	P	1,875	15	A	San Andres	2,253
110	25	0	0	3,915	3,900		44		Ellenburger, Ord	D	P	9,000	75	A	Ellenburger	9,301
111	7	186	1												Ellenburger	9,562
112	0	8	0				35	0.3	Queen, Per	S	P	2,375	40	A		
113	0	170	0				36	0.4	San Andres, Per	L-D	P	2,960	60	AD		
114	1	0	0						Word, Per	S	P	4,212		MC		

TABLE 1.—(*Continued*)

Line Number	*County*, Field	Year of Discovery	Area Proved, Acres[b]	Oil Production Total, Bbl.[e]		Producing Days, 1943	Gas Production, Millions Cu. Ft.[3]		Number of Oil and/or Gas Wells[f]		
				To End of 1943	During 1943		To End of 1943	During 1943	Completed to End of 1943	1943 Completed	1943 Abandoned
	Regan: Barnhart										
	Big Lake										
115	Ordovician	1928	1,300	29,054,172	469,508				25	0	0
116	Grayson	1928	320	677,490	31,087	249			7	0	1
117	*Runnels:* Beddo	1938	70	130,781	32,651	365			7	0	1
118	Huddleston	1940	20	18,771	4,020	249			2	0	0
119	McMillan	1927	190	960,336	2,267	249			18	0	0
		1942	20						2	1	0
120	Winters	1943	80	6,482	6,482	315			2	2	0
121	*Schleicher:* Page	1934	2,500	48,904	8,200	249	7,344	3,038	6	0	0
122	*Scurry:* Sharon Ridge (deep)	1938	3,400	1,720,863	363,703	244			114	8	0
123	*Scurry and Mitchell:* Sharon Ridge (shallow)	1924	3,800						72	1	4
124	*Tom Green:* Funk	1940	20	1,083	372	249			1	0	0
125	*Upton:* Herrington	1937	100	91,641	6,565	249			2	0	0
126	Hurdle	1936	300	256,948	14,998	365[2]			18	0	0
127	Webb Ray	1935	160	71,009	2,791	249			6	0	0
128	*Ward:* Byrd	1942	280	52,573	44,729	249	48.5	34.4	7	2	0
129	Dobbs	1936	80	21,969	1,941	365[2]			2	0	0
130	Estes	1936	4,500	15,619,397	1,454,890	267	48,576	7,186	368	1	5
131	Magnolia Sealy	1938	830	1,215,568	205,354	249			55	0	0
122	Magnolia Sealy South	1940	1,020	506,234	250,109	249	248	130	20	1	0
133	Monahans	1942	160	124,490	66,690	344	146.1	92.3	1	0	0
134	Monahans Permian	1942	320	16,579	10,749	230	14.2	8.4	1	0	0
135	Monroe	1930	80	85,331	5,769	365			2	0	0
136	North Ward	1929	10,000	27,229,685	2,265,190	244	97,809	7,695	425	1	0
137	Pruitt	1942	40	2,980	1,428	249			1	0	0
138	Pyote	1942	80	48,271	25,900	249	3.4	1.8	2	0	0
139	Shipley[7]	1928	2,700	6,139,713	476,644	246		221.4	146	7	10
140	Shipley Silurian	1940	400	44,976	6,935	249	632	85.4	2	0	0
141	South Ward	1930	10,500	28,005,116	866,289	249			701	0	26
142	Spencer	1941	400	126,387	76,957	249	188.5	37.6	10	0	0
		1943	40	1,810	1,810	153	0.4	0.4	1	1	0
143	*Winkler:* Eaves	1936	320	904,703	200,030	249		130	10	3	0
144	Emperor	1935	1,600	2,883,199	420,412	290		2,477	86	8	1
145	Emperor Deep	1940	2,000	1,017,101	112,275	249		190	49	1	4
146	Halley	1934	800	1,041,491	81,499	249		242	30	1	0
147	Halley Extension	1943	40	3,086	3,086	76	3.2	3.2	1	1	0
148	Henderson	1933	1,650	7,941,160	1,617,206	249	4,731	682	143	0	3
149	Hendrick	1926	12,200	206,418,809	2,072,946	365			425	0	30
150	Kermit	1928	15,240	30,970,542	1,274,207	333	93,828	7,132	848	0	2
151	Kermit Ellenburger	1943	160	55,359	55,359	250	97.7	97.7	1	1	0
152	Keystone Colby Sand	1930	8,080	6,433,612	1,220,019	249			274	10	0
153	Keystone Lime	1935	9,500	4,731,396	478,150	244	55,868	4,176	105	1	0
154	Keystone Ellenburger	1943	160	41,028	41,028	210	81.2	81.2	1	1	0
155	Keystone Holt	1943	160	3,607	3,607	43	3.3	3.3	1	1	0
156	Leck	1927	960	4,048,311	142,991	365			9	0	0
157	Scharborough	1927	2,000	7,467,400	436,886	249		1,498	138	0	0
158	Weiner	1941	2,000	353,573	270,416	249		264	38	15	0
159	Wheeler Ellenburger	1943	160	40,587	40,587	175	56.5	56.5	1	1	0
160	*Yoakum:* Ownby	1941	560	123,651	52,898	249	99	53.6	10	4	0
161	Waples Platter	1939	600	96,754	32,992	249			7	3	0
162	West	1938	40	49,869	7,280	249			1	0	0

[7] Includes Nichols field.

TABLE 1.—(*Continued*)

Line Number	Wells Producing[g] Dec. 1943			Reservoir Pressure, Lb. per Sq. In.		Secondary Recovery[h]	Character of Oil[i]		Producing Formation						Deepest Zone Tested[p] to End of 1943	
	Oil: Flowing	Oil: Artificial Lift	Gas	Initial	Avg./End 1943		Gravity A.P.I. at 60°F.	Sulphur, Per Cent	Name and Age[j]	Character[k]	Porosity, Per Cent[l]	Depth to Top of Producing Zone, Ft.[m]	Productive Thickness, Avg. Ft.,[n] Net	Structure[o]	Name	Depth of Hole, Ft.
115	6	8	1	3,600			44	0.1	Ellenburger, Ord	D	P	8,200		A		
116	0	5	0				33	0.58	Grayburg, Per	OD	P	3,063	14	D	Strawn	9,969
117	0	5	0				42		Pen	S	P	2,366	22	N		
118	0	1	0				39		Palo Pinto, Pen	L	P	3,557	26	N	Palo Pinto	
119	0 1	0 0	0 0				41		Graham, Pen	S	P	2,550 3,522	12	N		
120	0	2	0				42		Avis or King Sand, Cisco	S	P	2,464			Ellenburger	4,735
121	1	0	5		1,100		38	0	Strawn, Pen	L	20	5,400	65	A	Ellenburger	7,011
122	15	99	0				30		San Angelo, Clear Fork, Per	D & S	P	2,250		A	Wichita	3,545
123	0	68	0				29		San Andres, Per	DL	P	1,650		A	Wolfcamp	4,524
124	0	1	0				33		San Andres, Per	DL	P	1,123	4	MC	Clear Fork	1,560
125	0	2	0				24		Grayburg, Per	DL	P	2,800	20	A	Grayburg	2,963
126	0	12	1				27		Grayburg, Per	DL	P	2,050	20	A	Lower Permian	3,085
127	0	2	0				25		Grayburg, Per	DL	P	2,060	20	A	San Andres	2,176
128	6	1	0	1,435	1,235		30	1.6	Yates, Per	S-D	P	2,607	16	A	Capitan	2,885
129	0	1	0				37		Queen, Per	S	P	2,550	7		Grayburg (?)	2,600
130	191	134	2	1,375		W	34	1.2	Yates, Per	S & D	P	2,450	40	A	Queen	3,274
131	1	52	0				32		Yates, Per	S & D	P	2,878	30	A	Seven Rivers	3,175
132	18	1	0	1,385	1,376		28		Seven Rivers, Per	O-D	P	2,890	15	A	Queen	3,277
133	1	0	0	4,700	4,650		47	0.2	Ellenburger, Ord	D	Cav Frac.	10,082		A	Ellenburger	10,545
134	1	0	0	2,340	2,340		34	0.8	Tubb-Clear Fork, Per	D	P	5,631	20	A	Ellenburger	10,545
135	1	0	0				29	0.14	Delaware, Per	S	P	4,665	5	T	Delaware	4,692
136	213	201	2	1,400		G	36	1.8	Yates, Per	D-S	P	2,500	40	ML	San Andres	4,825
137	0	1	0						Delaware, Per	S	P	4,831		A	Delaware	4,869
138	2	0	0	1,430	1,430		20	1.8	Capitan, Per	D	8	2,827	9.5	A	Capitan	3,100
139	8	123	5				35	1.8	Seven Rivers-Queen, Per	DS	P	2,480-3,000	60	A	Ellenburger	9,187
140	2	0	0	3,281	3,076		32	0.3	Silurian, Sil	L	P	7,000	50		Ellenburger	9,187
141	113	446	6	1,370			32	1.3	Seven Rivers, Per	S	P	2,300	40	ML	Wichita (?)	4,825
142	2	8	0	1,430	1,365		28	0.6	Capitan, Per	OD	8	2,926	20	A	Capitan	3,000
	1	0	0	960	960		30	1.6	Yates, Per	S-D	P	2,765	8	A	Capitan	3,000
143	5	5	0				26		Yates, Per	S-SD	P	3,100	20	A	Seven Rivers	3,175
144	72	13	0	1,300			33		Yates, Per	S-SD	18.8	2,700	65	A	San Andres	3,480
145	28	10	7						Seven Rivers, Per	OD	P	2,785	20	AC	Seven Rivers	3,100
146	5	22	2	1,235			31		Yates, Per	S-SD	P	2,730	65	A	San Andres	3,855
147	0	1	0				33		White Horse, Per	DS	P	3,191	3	A	White Horse	3,194
148	107	33	0	1,450	1,278		30	1.1	Seven Rivers, Per	OD	P	3,025	30	A	Grayburg (?)	3,450
149	36	239	1	1,720			28	1.5	Seven Rivers, Per	OD	P	2,600		A	San Andres	3,920
150	128	664	22	1,450		G-W	35	1.5	Yates, Per	DS	P	2,825	40	A	Grayburg	3,414
151	1	0	0	4,643			43		Ellenburger, Ord	D	Frac.	10,460	245	A	Ellenburger	10,774
152	192	73	1				36		Grayburg, Per	S-D	P	3,215		A	Ellenburger	10,774
153	70	32	1	1,573			36	0.8	San Andres, Per	D-S	P	3,200		A	Ellenburger	10,655
154	1	0	0	4,252	4,252		43	0.1	Ellenburger, Ord	D	Frac.	9,217	131		Ellenburger	9,655
155	1	0	0				39		Holt, Per	D	P	4,705		A	Clear Fork	4,900
156	1	8	0				28	1.6	Seven Rivers, Per	OD	P	3,000		A	San Andres	3,780
157	58	67	0				35	1.0	Yates, Per	S-D	P	2,800	10	A	Grayburg (?)	3,565
158	33	4	1	1,270			33		Queen, Per	S	P	3,025	40	A	San Andres	3,896
159	1	0	0	4,583	4,579		45	0.14	Ellenburger, Ord	L	P	10,493	55	A	Ellenburger	10,697
160	10	0	0	1,638	1,563		31	0.1	San Andres, Per	D	P	5,235	27	A	San Andres	5,700
161	3	4	0	1,465	1,241		32	0.1	San Andres, Per	D	P	5,200	25	A	San Andres	5,380
162	0	1	0				31		San Andres, Per	D	P	5,168	10	MC	San Andres	5,255

TABLE 2.—*Summary of Drilling Operations in West Texas*

Important Wildcats Drilled in 1943

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Block	Survey			
1	Andrews	12	A-32	P.S.L.	7,381	Tertiary to Recent	Lower Clear Fork-Per
2	Andrews	8	A-34	P.S.L.	10,596	Tertiary to Recent	Strawn Bend-Pen
3	Andrews	20	A-38	P.S.L.	8,416	Tertiary to Recent	Wolfcamp-Per
4	Andrews	16	13	Univ.	7,458 7,177 P.B.	Tertiary to Recent	Lower Clear Fork-Per
5	Andrews	28	9	Univ.	7,500 5,550 P.B.	Tertiary to Recent	Lower Clear Fork-Per
6	Andrews	28	1	Univ.	8,437	Tertiary to Recent	Clear Fork-Per
7	Andrews	37	40	T. 2 N.G. & M.M.B. & A.	4,770 4,704 P.B.	Tertiary to Recent	Grayburg-Per
8	Andrews	19	A-31	P.S.L.	7,459	Tertiary to Recent	Lower Clear Fork-Per
9	Cochran	Lab. 2	Lge. 59	Martin Co. Schl. Lds.	4,945	Tertiary to Recent	San Andres-Per
10	Crane	2	13-28	P.S.L.	7,777 3,883 P.B.	Tertiary to Recent	Ellenburger-Ord
11	Crockett	12	"Q"	John Small	2,567 2,402 P.B.	Cretaceous	San Andres-Per
12	Crockett	16	"YZ"	E.L. & R.R.R.R.	7,903	Cretaceous	Ellenburger-Ord
13	Crockett		Lge. 3	Archer Co. Schl. Lds.	2,550 2,160 P.B.	Cretaceous	San Andres-Per
14	Gaines	196	"G"	W.T.R.R.	9,312 5,267 P.B.	Tertiary to Recent	Wolfcamp-Per
15	Gaines	92	"G"	W.T.R.R.	6,070	Tertiary to Recent	San Andres-Per
16	Gaines	458	"G"	C.C.S.D. & R.G.N.G.	7,772	Tertiary to Recent	Lower Clear Fork-Per
17	Gaines	5	"H"	D. & W.	11,954	Tertiary to Recent	Strawn Bend-Pen
18	Gaines	Lab. 5	Lge. 317	Parmer Co. Schl. Lds.	8,097	Tertiary to Recent	Clear Fork-Per
19	Hockley	21	"A"	R. H. Thompson	6,000 5,980 P.B.	Tertiary to Recent	Lower Clear Fork-Per
20	Howard	57	20	Lavaca Navigation Co.	4,096	Triassic	Clear Fork-Per
21	Martin	1	39	T. 3 N.G. & M.M.B. & A.	7,536	Tertiary to Recent	Clear Fork-Per
22	Pecos	24	140	T. & St. L.	4,565 4,220 P.B.	Recent	Pre-Cambrian
23	Pecos	44	"Z"	T.C.R.R.	1,857	Cretaceous	San Andres-Per
24	Pecos	15	20	Univ.	1,369	Cretaceous	White Horse-Per
25	Pecos	76	10	H. & G.N.	1,661	Recent	White Horse-Per
26	Pecos	16	142	T. & St. L.	7,608	Cretaceous	Delaware-Per
27	Pecos	29	3	H. & T.C.	8,315	Recent	Ellenburger-Ord
28	Pecos	96	10	H. & G.N.	3,557 3,546 P.B.	Recent	Clear Fork-Per
29	Pecos	101	11	H. & G. N.	4,103 4,079 P.B.	Recent	Ellenburger-Ord
30	Pecos	9	194	G.C. & S.F.	9,114	Cretaceous	Ellenburger-Ord
31	Reagan	13	1	T. & P.	9,995	Cretaceous	Ellenburger-Ord
32	Runnels	330	64	F. J. Ford	4,735 2,520 P.B.	Permian	Ellenburger-Ord
33	Schleicher	75	"TT"	T.C.R.R.	7,021	Cretaceous	Ellenburger-Ord
34	Scurry	258	97	T. & T.C.R.R.	8,336	Recent	Ellenburger-Ord
35	Sterling	8	30	W. & N.W.	9,587	Cretaceous	Ellenburger-Ord
36	Sterling	6	"A"	G.C. & S.F.	8,486	Cretaceous	Ellenburger-Ord
37	Sterling	3	31	T. 5 S.T. & P.	9,303	Cretaceous	Ellenburger-Ord
38	Sutton	25	"K"	G.H. & S.A.	3,761	Cretaceous	Canyon-Pen
39	Upton	5		G.C. & S.F.	8,358 7,224 P.B.	Cretaceous	Ellenburger-Ord
40	Winkler	1	B-3	P.S.L.	9,655	Recent	Ellenburger-Ord
41	Winkler	4	B-3	P.S.L.	10,774 10,707 P.B.	Recent	Ellenburger-Ord
42	Winkler	5	B-2	P.S.L.	4,900 4,800 P.B.	Recent	Clear Fork-Per
43	Winkler	15	46	T. 1 S. T. & P.	10,697	Recent	Ellenburger-Ord
44	Winkler	19	B-11	P.S.L.	3,194	Recent	White Horse-Per
45	Yoakum	315	"D"	J. H. Gibson	7,600	Recent	Lower Clear Fork-Per
46	Yoakum	840	"D"	J. H. Gibson	7,950	Recent	Lower Clear Fork-Per
47	Yoakum	748	"D"	J. H. Gibson	7,995	Recent	Upper Clear Fork-Per

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1943

	Drilled by	Initial Production per Day: Oil, U. S. Bbl.	Initial Production per Day: Gas, Millions Cu. Ft.	Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.: Casing	Pressure, Lb. per Sq. In.: Tubing	Remarks
1	C. U. Bay	850	0.978	¾			Discovery East Fullerton field
2	Humble Oil & Ref. Co.						Dry and abandoned
3	Magnolia Petr. Corp.						Dry. Temp. abandoned
4	Mid-Continent Petr. Corp.	179	0.116	3/16	825	450	Extension Fullerton field
5	Skelly Oil Co.	Pump 180 fluid 177 oil		2½(+bg.)			Discovery Clabberhill field
6	Skelly Oil Co.						Dry and abandoned
7	Texas Co.	Swab 149 in 11½ hr		2(+bg.)			Discovery Mabee field
8	Union Oil Co. of Calif.	460	0.12	49/64			Discovery Union field
9	Sunray Oil Co.	229 + 2%	0.149				Extension Slaughter field
10	Gulf Oil Corp.	Pump 18 fluid 17 oil	0.01	2(+bg.)			Discovery Sand Hills West field
11	Moore Bros.	Pump 55 fluid 45 oil					Discovery Shannon field
12	Moore Bros.						Dry and abandoned
13	Turner & Phillips		10.0				Discovery Turner gas field
14	Amerada Petr. Corp.	453	0.483				Seminole field well
15	Gulf Oil Corp.						Dry and abandoned
16	Shell Oil Co.	Pump 213	small	2(+bg.)			Discovery Russell field
17	Stanolind Oil & Gas Co.						D. & A. Cedar Lake field
18	Texas Co.						Junked and abandoned
19	Woodley Petr. Corp.	Pump 161					Discovery Smyer field
20	W. S. Guthrie & Cosden Petr. Corp.	Pump 162	0.081				Discovery Vincent field
21	Mid-Continent Petr. Corp.						Dry and abandoned
22	Anderson-Prichard Oil Corp.						Gas Well. Shut In
23	Cardinal Oil Co.	44 fluid 40 oil	0.016	open tbg.			Discovery White and Baker lime field
24	Kidd & Cherry	Pump 10					Discovery Mule Creek field
25	E. Russell Lloyd	88	0.039				Discovery Apco 1600-ft. field
26	Magnolia Petr. Corp.						Dry and abandoned
27	Magnolia Petr. Corp.						Dry and abandoned
28	Magnolia Petr. Corp.	83 oil plus 197 water		Gate valve			Discovery Masterson 3500-ft. field
29	Bryce McCandless	65 in 3 hr.		1/64			Discovery McCandless field
30	Standard Oil Co. of Texas						Dry and abandoned
31	Humble Oil & Ref. Co.						Dry and abandoned
32	Pawnee Royalty Co.	Pump 91 oil plus 140 water					Discovery Winters field
33	Geo. P. Livermore & E. N. Wahlenmaier						Dry and abandoned
34	Humble Oil & Ref. Co.						Dry and abandoned
35	Col Tex Ref. Co.						Dry and abandoned
36	Ohio Oil Co.						Dry and abandoned
37	Phillips Petr. Co.						Dry and abandoned
38	S. B. Roberts		6.64				Gas well
39	T. P. Coal & Oil Co.	398	0.689				Discovery McCamey Silurian field
40	Amon G. Carter	6,790	10.64	¾			Discovery Keystone Ellenburger field
41	Magnolia Petr. Corp.	588 oil plus 12 water	1.025	¼			Discovery Kermit Ellenburger field
42	Richardson & Bass	251	0.228	33/64			Discovery Keystone Holt field
43	Stanolind & Shell	1,370	2.007	25/64			Discovery Wheeler Ellenburger field
44	Sunray Oil Co.	164	0.172	¾			Discovery Halley Extension field
45	Barnsdall Oil Co.						Dry and abandoned
46	Humble Oil & Refg. Co.						Dry and abandoned
47	Hugh M. Stoddard Trustee						Dry and abandoned

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1943	290	71
Number of oil wells completed during 1943	732	23
Number of gas wells completed during 1943	5	3
Number of dry holes completed during 1943	59	80

cessful well completion. A control of mud characteristics is required, first, to reduce water filtration from the mud to porous zones, as this permits the building of thick mud cake and causes "tight hole," with danger of stuck drill pipe or casing, and second, to combat caving shale, which causes hole "fill up" during round trips and hole enlargement, with reduction in annular fluid velocities. In general, the cheapest and most efficient control consists in cementing sufficient casing to exclude the salt section and to permit the use of 9.5 to 10 lb. per gallon fresh-water mud consisting of bentonite and barite. Where necessary, small amounts of caustic, quebracho and starch may be added to the mud to give a satisfactory viscosity, gelation, and a very low water loss. The control of salt-water mud consists in the use of a Florida clay to provide viscosity and the use of starch to reduce water loss.

TABLE 3.—*Number of Completed Wells*

Year	1941	1942	1943
Field wells:			
Oil		1,052	732
Gas		69	5
Dry		10	59
Total	2,190	1,131	796
Wildcat wells:			
Oil	25	36	23
Gas		1	3
Dry		99	80
Total	135	136	106
Total wells drilled:			
Oil		1,088	755
Gas		11	8
Dry		168	139
Total	2,325	1,267	902
Wildcat percentage of total number of wells drilled	5.8	10.7	11.7

DIFFICULTIES IN DRILLING

Drilling in the Deep Devonian chert section has proved to be slow and costly. Where the drilling is particularly hard, a rock bit may cut less than a foot of chert. One company is experimenting with a diamond-studded core bit. In the first design, difficulty is encountered in retaining the diamonds on the bit. As yet no one has determined the feasibility of deep cable-tool drilling in the chert section.

One drilling contractor is experimenting with threaded and coupled drill pipe to determine the relative merits of long inexpensive couplings as compared to the more costly conventional tool joints. In instances where operators have elected to set casing above the pay, coring with reverse circulation has greatly increased the percentage of core recovery.

TABLE 4.—*Distribution of Wildcat Oil Wells*

Year	1941	1942	1943
New field discoveries		16	12
New productive horizons in old fields		3	7
Extensions to established fields		17	4
Total oil wells		36	23
Total wildcat wells		136	106
Percentage wildcat wells completed as oil wells	20.0	26.5	21.7

One operator reported the economic justification and mechanical success of a dual completion that was made in anticipation that oil from the lower formation will continue to flow while that from the upper formation is produced by pumping. In some fields, sulphur constituents of the upper oil formation has caused serious corrosion of casing.

PRORATION

The trend in proration continues toward reduction of the limits of unpenalized gas-oil ratio to a common base of 2000 cu. ft. per barrel. Through increased cooperation of the operators, there is a gradual improvement in bringing about these lower limits and generally conserving reservoir energy. During the period of low producing rates, few reservoir data were obtained in regard to maximum efficient producing rates. In some instances, this led to over-optimistic expression of opinion relative to the availability of proved reserves. In order to stimulate wildcat drilling and in some measure compensate the successful wildcatter in proportion to his drilling costs, the Railroad Commission of Texas has ordered that new productive horizons in old fields, new extensions to old fields, and new discoveries be granted a relatively high daily allowable graduated in accordance with well depth.

The "Production Unit Plan," under which operators are permitted to shut in wells of higher gas-oil ratio and transfer the allowable to wells of lower gas-oil ratio, has continued in effect in those fields previously reported. With depletion and increased allowables, the utility of the "Production Unit Plan" is restricted to pools in which the majority of wells are considerably prorated. In some instances, gas-oil ratios can be controlled by progressively reducing production rates. More uniform distribution of production and higher over-all efficient pool production may be obtained by permitting the transfer of the part of the allowable of a high gas-oil ratio well that is lost by reducing the producing rate.

CONSERVATION

Unless applicable secondary recovery methods are found, there will be an increasingly large number of wells abandoned in gas-drive fields during the next few years. The experimental injection of untreated water into depleted oil wells on 10-acre spacing in the Estes and Kermit fields has not advanced sufficiently to determine the economic application of water-flooding on a field-wide basis. Whereas considerable pressure is required in the Estes field to inject 500 bbl. of water per well per day, one well in the Kermit field will take more than 1000 bbl. per day under gravity.

The growing concern in regard to the availability of developed oil reserves to meet the nation's requirements for petroleum products has led to a new realization of the importance of both oil and gas conservation. As a consequence, the injection of gas for pressure maintenance in many reservoirs is receiving serious consideration. Engineering committees are studying the economic and reservoir factors involved in the field-wide application of pressure maintenance to the Colby, Slaughter, and Goldsmith fields. Since there are other large fields with similar reservoir characteristics, the conclusions reached may have far-reaching application. One of the interesting problems connected with these studies is the determination of the extent that experience gained from sand reservoirs may prove applicable to limestone and dolomite reservoirs. After three years experience in the North Ward field, one operator feels assured that pressure maintenance there is effective in substantially increasing ultimate oil recovery and is economically sound. The magnitude of the increased ultimate recovery has not been fully evaluated.

ELECTRIC PILOT

The growing use of the electric pilot for obtaining permeability profiles is very timely and applicable to this area. From these profiles, it is becoming apparent that one of the common characteristics of noncavernous dolomitic lime formations is the occurrence of definite zones of better permeability within the gross pay section. When

TABLE 5.—*Production of Crude in West Texas*[a]

1943	Wells		Reported Production, Bbl.	Runs to Pipe Line, Bbl.
	Flow	Pump		
January	7,741	7,383	6,265,210	6,261,269
February	7,735	7,408	6,050,138	5,975,350
March	7,715	7,415	6,714,038	6,642,671
April	7,780	7,433	6,518,287	6,500,641
May	7,741	7,443	7,109,910	7,100,682
June	7,821	7,503	6,967,944	6,941,337
July	7,845	7,531	7,664,833	7,870,186
August	7,959	7,472	8,102,477	8,018,418
September	7,938	7,518	10,066,374	9,867,935
October	7,928	7,588	11,175,900	10,926,557
November	7,979	7,613	10,582,751	10,534,153
December	7,958	7,746	10,946,950	10,965,373
Total			98,164,812	97,604,572

[a] Compiled from Railroad Commission of Texas monthly crude-oil reports.

TABLE 6.—*Distribution Field Well Development*—1943

County	Field	Number of Oil Wells	Dry and Abandoned	Number of Gas Wells	Oil Wells Drilled Deeper	Junked	Recompleted	Total	Total Footage Drilled
Andrews	Deeprock	2						2	8,868
	Embar	13						13	104,185
	Embar Permian	8	1					9	61,150
	Emma	2						2	8,551
	Fullerton	18		1		1		20	138,914
	Fuhrman	1						1	4,473
	Mascho	32	1			1		34	159,845
	Means	3					1	4	14,462
	North Cowden	3						3	14,072
	West Andrews		2					2	8,937
	West Fuhrman	13	(Combined with Mascho field 6-1-43)					13	59,841
	Total	95	4	1		2	1	103	583,298
Cochran	Dean	5						5	25,297
	Slaughter	104	1		1			106	527,859
	Total	109	1		1			111	553,156
Coke	Blackwell		1					1	3,748
Crane	Dune	1						1	3,201
	McElroy	1			1			2	3,075
	McKee	1	1					2	13,325
	Sand Hills Permian	16						16	75,937
	Total	19	1		1			21	95,538
Crockett	Clara Couch	2	1			1		4	8,470
	Crockett	1						1	1,607
	Olson	2		1				3	6,464
	Noelke	7	2	2	1		1	13	18,294
	World	11						11	28,779
	Total	23	3	3	1		2	32	63,614
Ector	Foster	8						8	34,643
	Goldsmith	15						15	63,520
	North Cowden	28			1		1	30	137,033
	North Goldsmith		1					1	6,499
	Penwell	1	1					2	7,324
	South Cowden	6						6	27,212
	Total	58	2		1		1	62	276,231
Gaines	Cedar Lake	3						3	14,466
	Russell	1						1	8,053
	Seminole	9						9	47,268
	Wasson	15	4					19	95,150
	Total	28	4					32	174,249
Glasscock	Howard-Glasscock	1			1			2	3,806
Hockley	Slaughter	162	1					163	810,869
Howard	Howard-Glasscock	4	1		1			6	10,435
	Iatan-East Howard	12	2			1		15	40,278
	Vincent		1					1	4,200
	Total	16	4		1	1		22	54,913
Lubbock	Stinnett		2					2	9,852
Mitchell	Westbrook	12	1					13	41,293
Pecos	Abell	5	2		1			8	41,018
	Abell Permian	2						2	4,656
	Apco-Warner	17	3	1				21	99,290
	Heiner	1						1	5,506
	Lehn	4	1					5	8,890
	Taylor Link	13	8		1			22	34,335
	Toborg	7	1					8	4,277
	Walker	12	2					14	29,198
	White & Baker	11						11	20,346
	Total	72	17	1	2			92	247,516
Reagan	Barnhart	14	1					15	138,230
	Big Lake		2					2	13,202
	Total	14	3					17	151,432
Scurry	Sharon Ridge	9			1		1[1]	11	23,284
Tom Green	Funk		1					1	1,175
Terry	Slaughter	4						4	20,170
Upton	McCamey	8			17			25	20,928

[1] Air well.

TABLE 6.—(*Continued*)

County	Field	Number of Oil Wells	Dry and Abandoned	Number of Gas Wells	Oil Wells Drilled Deeper	Junked	Recompleted	Total	Total Footage Drilled
Ward	Byrd	2	1					3	8,093
	Estes	1			6			7	3,954
	Magnolia Sealy-South	1	1					2	5,829
	North Ward	1	1					2	5,715
	Nichols		1					1	2,427
	Payton	1						1	2,090
	Pyote		1					1	2,899
	Pecos Valley, High Gravity	1						1	1,917
	Shipley	7						7	17,987
	Spencer	3	1					4	11,547
	South Ward				2[2]			2	851
	Total	17	6		8			31	63,309
Winkler	Eaves	3						3	9,555
	Emperor	8						8	22,982
	Emperor-Deep	1						1	2,965
	Halley	1						1	2,871
	Henderson		1					1	3,179
	Hendrick				1[3]			1	666
	Kermit				2			2	332
	Keystone Colby Sand	10	1		2			13	36,951
	Keystone Lime	1						1	3,443
	Weiner	15	2					17	54,150
	Total	39	4		5			48	137,094
Yoakum	Wasson	40	4					44	228,155
	Waples Platter	2						2	10,593
	Ownby	4						4	21,692
	Total	46	4					50	35,281
	Total Field Wells	732	59	5	39	6	2	843	3,595,915
	Total Wildcat Wells	23	80	3				106	551,404
	Total Drilled Wells	755	139	8	39	6	2	949	4,147,319

[2] Dry and abandoned.
[3] Dry hole.

used in conjunction with a bottom-hole pressure bomb, this instrument gives an indication of the relative permeability of the various zones open to the well bore. With continued research to improve the electric-pilot equipment and with a better understanding of its application and limitations, the electric pilot should become a valuable tool for use in studying limestone reservoirs.

West Texas produced 98,000,000 bbl. of crude during 1943. Table 5 shows a production increase of 84.5 per cent from a February low of 6,050,000 to an October high of 11,176,000 barrels.

PIPE LINES

With the increase in production, pipe lines were operated at capacity. To afford an outlet for 60,000 to 65,000 bbl. per day, the Humble Pipe Line Co. reopened its line to Ingleside, Texas. From January to August, the Humble ran 1,170,000 bbl. of oil to storage, and this was withdrawn from storage by December.

In September 1942, the Phillips Petroleum Co. placed in operation 55 miles of 6-in. and 231 miles of 8-in. line, connecting the McElroy field with Borger, Texas. During 1943, this line handled 866,485 bbl. of products gathered from Phillips gasoline plants in the McElroy, Penwell, Goldsmith and Hobbs fields.

In November 1943, the Atlantic Pipe Line Co. completed the construction at Midland, Texas, of a double-track loading rack with a capacity of 77 tank cars. With maximum employment of this loading rack, 300 cars may be loaded with 60,000 bbl. of crude per day. During 1943, the company shipped 4361 carloads of crude oil to eastern markets.

TABLE 7.—*New Discoveries during* 1943

	County	Field	Discovery Well	Total Depth, Ft.	Plug-back Depth, Ft.	Producing Horizon	Grav-ity	Top of Pay, Ft.	Gas-oil Ratio
			NEW FIELDS						
1	Andrews......	Clabberhill	Skelly Oil Co. No. 1-K University	7,500	5,550	Holt Zone of San Andres-Permian	33.0	5,464	(Pump)
2	Andrews......	Mabee	Texas Co. No. 1 J. E. Mabee	4,770	4,704	Grayburg-Permian	31.0	4,640	(Swab) 114[a]
3	Andrews......	Union	Union Oil Co. of Calif. No. 1 J. D. Biles	7,459		Lower Clear Fork-Permian	41.9	7,259	261
4	Crane........	Sand Hills West	Gulf Oil Corp. No. 1 W. A. Estes	7,777	3,883	San Angelo-Permian	34.7	3,830	(Pump) 574
5	Crockett......	Shannon	Moore Bros. No. 1-12 M. A. Shannon	2,567	2,402	San Andres-Permian	28.2	2,278	(Pump)
6	Gaines........	Russell	Shell Oil Co. No. 1 D. N. Leaverton	7,772		Lower Clear Fork-Permian	35.2	7,480	(Pump
7	Hockley......	Smyer	Woodley Petr. Co. No. 1 L. A. Harless	6,000	5,980	Lower Clear Fork-Permian	25.6	5,850	(Pump)
8	Howard......	Vinson	W. S. Guthrie & Cosden No. 1 Pauline Allen	4,096		Clear Fork-Permian	27.3	4,040	(Pump) 500
9	Pecos........	McCandless	Bryce McCandless No. 1-101 Atlantic Ref. Co.	4,103	4,079	Ellenburger-Ordovician	35.4	4,012	
10	Pecos........	Mule Creek	Kidd & Cherry No. 1-15 University	1,369		Whitehorse-Permian	36.0	1,355	Pump
11	Runnels......	Winters	Pawnee Royalty Co. No. 1 L. A. David	4,735	2,520	Avis or King Sand-Lower Cisco	42.0	2,464	Pump
12	Winkler......	Wheeler Ellenburger	Stanolind-Shell No. 1 W. D. Blue Est.	10,697		Ellenburger-Ordovician	45.9	10,493	1,392
			EXTENSIONS TO OLD FIELDS						
13	Andrews......	East Fullerton	C. U. Bay No. 1 Bitler & Lowe	7,381		Lower Clear Fork-Permian	42.0	6,900	1,150
14	Andrews......	Fullerton	Mid-Continent Petr. Corp. No. 1-B University	7,458	7,177	Lower Clear Fork-Permian	41.0	6,878	650
15	Cochran......	Slaughter	Sunray Oil Co. No. 1 Wright-Vaughn	4,945		San Andres-Permian	30.5	4,865	650
16	Winkler.......	Holley Extension	Sunray Oil Co. No. 2 M. J. Hill	3,194		Whitehorse-Permian	33.0	3,191	1,049
			DEEPER HORIZONS IN OLD FIELDS						
17	Pecos.........	Apco 1600 ft.	E. Russell Lloyd No. 1 Mrs. E. C. Powell	1,661		Whitehorse-Permian	35.2	1,649	440
18	Pecos.........	Masterson 3500 ft.	Magnolia & Anderson Prichard No. 1-96 State Powell	3,557	3,546	Clear Fork-Permian	21.9	3,539	
19	Pecos.........	White and Baker lime	Cardinal Oil Co. No. 4C White & Baker	1,857		San Andres-Permian	22.2	1,802	400
20	Upton........	McCamey Silurian	Texas Pacific Coal & Oil Co. No. 52-A John F. Lane	8,358	7,224	Fusselman-Silurian	43.8	7,125	1,732
21	Winkler......	Kermit Ellenburger	Magnolia Petr. Co. No. 20 State Walton	10,774	10,707	Ellenburger-Ordovician	41.7	10,673	1,744
22	Winkler......	Keystone Ellenburger	Amon G. Carter No. 2-C Pure-Walton	9,655		Ellenburger-Ordovician	40.7	9,550	1,567
23	Winkler......	Keystone Holt	Richardson & Bass No. 4 J. B. Walton	4,900	4,800	Holt Zone of San Andres-Permian	39.4	4,705	908
			NEW GAS FIELDS						
24	Crockett......	Turner	Turner & Phillips No. 1 Shannon Est.	2,550	2,160	Whitehorse-Permian		1,895	Perforated casing

[a] Undersaturated.

During the year, construction was started by the Stanolind Pipe Line Co. on 365 miles of 16-in. pipe line for crude oil from the Slaughter field to Drumright, Oklahoma. With the addition of seven pump stations, the estimated capacity of this line may be increased from 65,000 to 116,000 bbl. per day.

The Magnolia Pipe Line Co. started construction on 333 miles of 12-in. line from Midland to Corsicana, Texas. By the addition of three pump stations, the estimated capacity of this line may be increased from 42,000 to 60,000 bbl. per day. This same company completed the looping of 46 miles of 8-in. line from the Seminole field to Midland, Texas.

TABLE 8.—*Distribution of Wildcat Development*, 1943

County	Number of Oil Wells	Dry and Abandoned	Number of Gas Wells	Total	Total Footage Drilled
Andrews....	5	6		11	74,874
Borden.....		2		2	4,518
Cochran....	1	2		3	15,408
Coke.......		1		1	1,851
Crane.......	1	2		3	16,583
Crockett....	1	6	1	8	25,219
Crosby......		1		1	3,515
Dawson.....		1		1	5,512
Ector.......		2		2	9,631
Gaines......	1	4		5	43,205
Garza.......		1		1	3,924
Hockley.....	1	4		5	30,525
Howard.....	1	1		2	7,038
Irion.......		1		1	2,527
Lubbock....		2		2	11,242
Martin......		2		2	12,738
Mitchell....		3		3	7,118
Pecos.......	5	17	1	23	99,562
Reagan.....		1		1	9,995
Reeves......		1		1	5,008
Runnels.....	1			1	4,735
Schleicher...		1		1	7,021
Scurry......		3		3	16,349
Sterling.....		5		5	32,779
Sutton......		1	1	2	8,197
Terry.......		1		1	5,553
Tom Green..		2		2	6,384
Upton......	1			1	6,207
Ward.......		2		2	8,130
Winkler.....	5			5	30,775
Yoakum....		5		5	35,281
Totals....	23	80	3	106	551,404

With the completion of the Stanolind and Magnolia pipe lines early in 1944, the pipe-line capacity from the West Texas-New Mexico area will be increased from 401,000 to 508,000 bbl. per day. By the building of additional pump stations and by the maximum use of tank-car shipments, the marketing outlet from the Permian Basin may be further increased to 637,000 bbl. per day.

ELLENBURGER PRODUCTION

The opening of Ellenburger production in the Kermit, Keystone and Wheeler fields in Winkler County was one of the significant developments of 1943. Like the Monahans field, to the south in Ward County, these Ellenburger fields are situated near the western edge of the Central Basin Platform in an area largely leased for Permian production.

In May 1943, the Magnolia Petroleum Corporation's No. 20 State-Walton was completed, flowing naturally 588 bbl. of 41.7° A.P.I. gravity oil from a depth of 10,705 ft., after being plugged back from a total depth of 10,774 ft. Below the Ellenburger top at 10,450 ft., a gas-distillate cap about 190 ft. thick was found above the oil zone, which was topped at 10,640 ft. As the oil-water contact was found at 10,705 ft., the well has 65 ft. of net pay thickness.

This discovery was shortly followed by the completion of Amon G. Carter's No. 2-C Walton, which obtained a potential of 6789 bbl. of oil per day. There was about 330 ft. of gas and distillate-bearing section between the Ellenburger top at 9217 ft. and top of the oil section at 9550 ft. The well was finished at a total depth of 9655 ft. without encountering bottom water.

In July, the Stanolind-Shell No. 1 Blue set pipe at a total depth of 10,697 ft. and gun-perforated from 10,647 to 10,697 ft., from which section the well tested 1370 bbl. of oil per day. The top of Ellenburger was reached at 10,493 feet.

Because of a difference of more than 1200 ft. in structural elevation between the Keystone and Kermit Ellenburger fields, within a distance of about 3½ miles, it is assumed that they are separate fields.

Consequently, the finding of a favorable structural trap is more important than finding the top of the Ellenburger high. If this hypothesis proves correct, exceedingly deep drilling will be required to test the Ordovician possibilities in the Permian Basin of West Texas.

LEASING

Leasing activity was heavy and general throughout the area with rising prices. At the December competitive University Lands sale, the Mid-Continent Petroleum Corporation bid the record price of $405,000 for a 320-acre tract 2½ miles south of production in the Fullerton field. The University received $3,643,600 for leases on 40,380 acres of land.

ACKNOWLEDGMENT

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Oil and Gas Development in West Virginia during 1943

By David B. Reger,[*] Member A.I.M.E.

Sharp declines of initial production of both oil and gas occurred in West Virginia during 1943. There was only a small decrease in the number of new wells, but these wells did not show the quantities of oil and gas that might have been expected. The same situation prevailed both as to routine drilling in old pools and as to exploratory wildcat wells. Out of 42 wildcats drilled, 19 resulted in small commercial gas wells, and 2 in small commercial oil.

Table 1.—*Production Statistics, West Virginia*

Period	Oil		Average Oil per Well Daily, Bbl.	Gas		Average Gas per Well per Day, Cu. Ft.
	Number of Wells	Bbl. Produced		Number of Wells	Million Cu. Ft. Produced	
To end of 1943		424,687,000			7,318,651	
During 1942	17,051	3,574,000[a]	0.57	14,114	215,193[a]	41,772
During 1943	16,872	3,349,000[b]	0.54	14,309	210,000[c]	40,208

[a] U. S. Bureau of Mines, final figures.
[b] U. S. Bureau of Mines, estimate.
[c] Author's estimate.

No new oil pools were discovered, but the proved limits of several old pools were considerably extended, giving 4200 acres of newly proved oil territory. Three new gas pools, resulting from discoveries made in 1942 and former years, came into definite activity. The newly proved gas territory in these and in various extensions of old pools is 39,000 acres or more. It is doubtful whether the newly proved reserves of either oil or gas will balance current withdrawals.

The account of operations, as gathered from trade journals and other reporting services, shows that 696 new wells were drilled, resulting in 82 oil wells with 919 bbl. of daily new production; 475 gas wells with 454,735,000 cu. ft. of daily open flow, and 137 dry holes. Also, 57 old wells were drilled to deeper sands, with 3 bbl. and 11,484,000 cu. ft. of added production. On the new wells, the oil average was 11.2 bbl. per well per day, and the gas average was 957,337 cu. ft. per well per day. On new wells the ratio of dry holes to completions was 19.68 per cent. On deeper drilling the ratio of failures was 14.03 per cent. The greatly decreased average initial gas-well production in 1943, as compared with 2,270,406 cu. ft. per well in 1942, is directly attributable to the abrupt decline of completions in the Charleston gas field, which reached its peak in 1942.

Production of oil for the year was estimated by the U. S. Bureau of Mines as 3,349,000 bbl., as compared with 3,574,000 bbl. in 1942.

Production of natural gas for the year is estimated by the author as 210,000,000,000 cu. ft., compared with the U. S. Bureau of Mines final figures of 215,193,000,000 cu. ft.[*] in 1942.

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[*] Consulting Geologist, Morgantown, West Virginia.

[*] The Public Service Commission of West Virginia reports (by letter) 248,142,275,000 cu. feet.

TABLE 2.—*New Pools and Extensions*

Pool (Oil and Gas), County and Producing Sand	Period	Wells, Initial Production and Proved Territory							Wells Drilling, End of 1943
		Oil		Gas			Dry Holes	Proved Acres	
		Number of Wells	Avg. Bbl. per Well per Day	Number of Wells	Average M Cu. Ft. per Well per Day	Average R.P., Lb.			
Bulltown (gas),[a] Braxton—B. I., 30-ft., G. Stray, Gord., 5th.	Before 1943	0		6	4,362[b]	616	6	1,000	
	During 1943	0		0			2	0	
	Total	0		6	4,362[b]	616	8	1,000	0
Barboursville (gas), Cabell—Berea, B. Shale	Before 1943	0		24	181	447	1	11,200	
	During 1943	0		2	134	485	0	600	
	Total	0		26	171	450	1	11,800	0
Sycamore (oil), Calhoun—B. I.	Before 1943	45	16.4	5	184	350	2	1,600	
	During 1943	9	12.8	2	327		0	100	
	Total	54	15.3	7	241	350	2	1,700	5
Morocco (gas), Clay—B. Lm., B. I.	Before 1943	0		11	1,285		1	1,000	
	During 1943	0		0			1	0	
	Total	0		11	1,285		2	1,000	4
Reed Fork (oil), Clay—B. I.	Before 1943	90?		?			?	1,000	
	During 1943	6	8	0			0	300	
	Total	96?	?	?			?	1,300	2
Villa Nova (gas), Braxton and Clay—Salt, Blue M., B. Lm., B. I.	Before 1943	2	50	71	1,323	492	37	12,000	
	During 1943	0		33	493	448	3	7,000	
	Total	2	50	104	1,077	477	40	19,000	8
Wade Fork (gas), Clay—Salt, Knr., B. I.	Before 1943	2	6	13	1,542	443	4	2,500	
	During 1943	0		2	596	510	1	1,000	
	Total	2	6	15	1,396	450	5	3,500	2
Charleston gas field (excluding Higginbotham Run oil pool and Rocky Fork gas pool), Jackson, Kanawha and Putnam—Oriskany	Before 1943	1	150	835	5,700	1,450?	66	130,000	
	During 1943	0	0	80	2,822	1,200	10	10,000	
	Total	1	150	915	5,449	1,437?	76	140,000	
Rocky Fork (gas, new) Kanawha and Putnam—B. Lm.	Before 1943	0		1	3,499	560	0	0	
	During 1943	0		13	4,285	581	1	1,400	
	Total	0		14	4,229	578	1	1,400	7
Eighteen-mile Fork (gas), Kanawha—Sq., Be.	Before 1943	0		7	203	473	0	150	
	During 1943	0		2	96		0	150	
	Total	0		9	172	473	0	300	2
Higginbotham Run (oil), (within Charleston gas field) Kanawha—B. Lm.	Before 1943	20	124	2	293		6	200	
	During 1943	2	35	0			3	0	
	Total	22	112.3	2	293		9	200	1
Bradyville ((gas), Lincoln—B. Lm., B. I., Be, B. Sh.	Before 1943	0		7	334	421	0	400	
	During 1943	0		5	1,190		0	300	
	Total	0		12	691	421	0	700	2
Griffithsville (oil), Lincoln—Be.	Before 1943	405(?)		?				12,000	
	During 1943	5	2.2	1	2,055		1	3,700	
	Total	410(?)		?				15,700	2
Spurlockville (gas), Lincoln—Be., B. Sh.	Before 1943	0		55+	400	398	4	19,000	
	During 1943	0		24	359	425	0	3,000	
	Total	0		79+	385	400	4	22,000	14
Heizer (gas), Putnam—B. Lm.	Before 1943	0		1	232	750	3		
	During 1943	0		5	2,241	569	4	1,200	
	Total	0		6	1,906	685	7	1,200	0
Trace Fork (gas), Putnam,—Salt, B. Lm., Be., B. Sh.	Before 1943	1	45	104	640	499	5	23,000	
	During 1943	0		29	210	353	0	0	
	Total	1	45	133	548	484	5	23,000	8
Slab Fork (gas), Raleigh—S. G., Max., B. Lm.	Before 1943	0		10	857	515	1	1,000	
	During 1943	0		5	950	547	4	1,900	
	Total	0		15	888	527	5	2,900	6
Lost Run (gas), Taylor—B. I.	Before 1943	0		8	205	233	4	700	
	During 1943	1	10	3	301	241	1	100	
	Total	1	10	11	253	237	5	800	1
Evergreen (gas); Upshur—Weir, Gord., 4th, 5th, Ball., Ril., Ben.	Before 1943	0		35	481	573	9	4,500	
	During 1943	0		10	528	438	5	500	
	Total	0		45	493	530	14	5,000	3

[a] Abbreviations as follows: Be., Berea; B. I., Big Injun; Ball., Balltown; B. Lm., Big Lime; Ben., Benson; Blue M., Blue Monday; B. Sh., Brown Shale; 5th, Fifth; 50-ft., Fifty-foot; 4th, Fourth; Gord., Gordon; G. Stray, Gordon Stray; Knr. Keener; Max., Maxton; Pr. Princeton; Ril, Riley; Sec. C. R., Second Cow Run; Sq., Squaw, S. G., Stony Gap.; 30-ft., Thirty-foot.

[b] Includes a 1914 wildcat of 25,000 M cu. ft., which soon exhausted.

TABLE 2.—(*Continued*)

Pool (Oil and Gas), County and Producing Sand	Period	Wells, Initial Production and Proved Territory							Wells Drilling, End of 1943
		Oil		Gas					
		Number of Wells	Avg. Bbl. per Well per Day	Number of Wells	Average M Cu. Ft. per Well per Day	Average R.P., Lb.	Dry Holes	Proved Acres	
Lorentz (gas), Upshur—50-ft., Gord., 5th, Ben.	Before 1943	0		22	375	1,112	3	3,500	
	During 1943	0		12	430	1,363	1	500	
	Total	0		34	394	1,192	4	4,000	5
Rock Cave (gas), Upshur—B. I., Sq., G. Stray, Gord., 5th, Ril., Ben.	Before 1943	0		13	505	541	0	1,200	
	During 1943	0		14	364	640	4	3,000	
	Total	0		27	445	583	4	4,200	3
Crum (gas), Wayne—Salt, B. Lm., B. I., B. Sh.	Before 1943	1	2	8	1,671	509	4	1,000	
	During 1943	0		5	1,348	333	0	3,000	
	Total	1	2	13	1,549	436	4	4,000	10
Ogdin (oil) Wood—Sec. C. R., Be.	Before 1943	27?	23.5?	1?	134?	280?	1?	1,500	
	During 1943	8	22.9	0	0		2	100	
	Total	35?	23.4?	1?	134?	280?	3?	1,600	5
Glen Morrison (gas), Wyoming—Pr., B. Lm.	Before 1943	0		7	339	467	1	1,800	
	During 1943	0		1	210	365	0	1,200	
	Total	0		8	321	441	1	3,000	1
Pineville (gas), Wyoming—Pr., Max., B. Lm., Be.	Before 1943	0		3	424	677	0	200	
	During 1943	0		9	1,202	634	1	4,300	
	Total	0		12	1,007	643	1	4,500	5

GENERAL STATE OF INDUSTRY

Leasing of wildcat acreage continued to be active. The land of all classes under lease probably exceeds 5,000,000 acres. Taking into consideration completions, abandonments and corrected figures or estimates, Table 1 shows cumulative and late annual statistics.

NEW POOLS AND EXTENSIONS

Table 2 shows the principal areas of drilling activity during 1943. Various consolidations of territory, hitherto treated as separate pools, have been made. In addition to these, considerable drilling was done in numerous other pools, and in areas where pool boundaries can hardly be defined.

SUMMARY OF EXPLORATION

Table 3 gives a summary of important wildcat or exploratory wells drilled during 1943, together with some others that have gone to unusual depths in old fields.

DEVELOPMENT IN ORISKANY AND OTHER DEEP SANDS

Drilling to the deep Oriskany sand (L. Dev.) declined severely in 1943, the total count showing 105 tests, of which 80 had commercial Oriskany gas. All of the productive wells are in the Charleston gas field of Jackson, Kanawha and Putnam Counties. A deep test in Tucker County was showing gas in the top of the Oriskany, but its completion has been delayed because of lost tools. (For completed Oriskany wildcats, see Table 3.)

In the Charleston field, as summarized in Table 4, drilling continued, but the limits apparently are well defined except to the south and southwest. The total production in this field has been about 550 billion cu. ft., of which about 100 billion were taken out in 1943. The field should continue to produce rather large quantities of gas for several years.

Seven wells were drilled to the Newburg sand (Sil.), three of which, in Boone and

TABLE 3.—*Important Wildcats Drilled in West Virginia during 1943*

Line No.	County	Magisterial District	Location		Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Property and Well No.	Initial Production per Day		Tubing or Casing Pressure, Lb. per Sq. In.	Remarks
			Latitude	Longitude						Oil Bbl.	Gas Millions Cu. Ft.		
1	Braxton	Birch	2.92 mi. S. of 38°40′	2.19 mi. W. of 80°50′	2,063	Pen-Conemaugh	L. Mis-Pocono	South Penn N. G. Co.	N. B. Cunningham, 1	0	0	0	Dry through Big Lime
2	Braxton	Salt Lick	4.73 mi. S. of 38°55′	3.35 mi. W. of 80°30′	2,930	Pen-Conemaugh	U. Dev-Catskill	W. Va. Gas Corp.	T. L. Skinner, 1-B-1	0	0	0	Dry through Bayard
3	Braxton	Salt Lick	1.10 mi. S. of 38°50′	3.65 mi. W. of 80°30′	2,301	Pen-Conemaugh	U. Dev-Catskill	Pittsburgh & W. Va. Gas Co.	G. W. Fleming, 1-7938	0	0	0	Dry through Fifth
4	Calhoun	Washington	2.13 mi. S. of 38°45′	4.34 mi. W. of 81°05′	2,115	Perm-Dunkard	U. Mis-Mauch Chunk	G. D. Jones	Curtis Walbrown, 1	0	0.280		Maxton gas well
5	Clay	Henry	3.30 mi. S. of 38°30′	4.14 mi. W. of 80°55′	1,955	Pen-Allegheny	L. Mis-Pocono	Thompson Gas Co.	Mont. Cavender, 1-T61	0	0.074	493 (48 hr.)	Big Injun gas well
6	Clay	Union	1.57 mi. S. of 38°25′	3.68 mi. W. of 81°10′	2,202	Pen-Allegheny	L. Mis-Pocono	Southeastern Gas Co.	Porters Creek C. & C. Co., 1-798	0	0.492	510 (48 hr.)	Big Injun gas well
7	Clay	Pleasant	3.89 mi. S. of 38°25′	3.28 mi. W. of 81°05′	2,202	Pen-Allegheny	L. Mis-Pocono	E. L. & O. G. Osborne	Betty Mullins, 1	0	0.033	500	Big Injun gas well
8	Clay	Pleasant	5.28 mi. S. of 38°25′	1.02 mi. W. of 81°05′	2,240	Pen-Kanawha	L. Mis-Greenbrier	Elk River Gas Co.	Stephenson, 1	0	0	0	Dry through Big Lime
9	Clay	Henry	2.52 mi. S. of 38°30′	0.75 mi. W. of 81°00′	1,942	Pen-Kanawha	L. Mis-Pocono	Pittsburgh & W. Va. Gas Co.	Elk River C. & L. Co., 52-7925	0	0.044	278 (95 hr.)	Big Injun gas well
10	Gilmer	Center	5.12 mi. S. of 38°55′	3.92 mi. W. of 80°55′	6,302	Pen-Conemaugh	L. Dev-Oriskany	Hope N. G. Co.	Susan Stump, 4-8655	0	0.295		Salt and Maxton gas well; dry in Oriskany
11	Jackson	Ripley	5.45 mi. S. of 38°45′	3.55 mi. W. of 81°40′	5,003	Perm-Dunkard	L. Dev-Oriskany	Godfrey L. Cabot, Inc.	J. L. McLean Hrs., 25-1082	0	0.467	1770 (19 hr.)	Oriskany gas well
12	Jackson	Ripley	3.14 mi. S. of 38°50′	4.32 mi. W. of 81°40′	4,835	Perm-Dunkard	L. Dev-Oriskany	Columbian Carbon Co.	Evalyn Rankin, 1-GW-717	0	0	0	Dry through Oriskany
13	Kanawha	Union	5.50 mi. S. of 38°35′	2.88 mi. W. of 81°40′	4,835	Pen-Monongahela	L. Dev-Oriskany	Godfrey L. Cabot, Inc.	R. E. Beane, 1-1066	0	0.239		Oriskany gas abandoned
14	Kanawha	Loudon	5.20 mi. S. of 38°20′	2.85 mi. W. of 81°35′	4,543	Pen-Kanawha	L. Dev-Oriskany	United Fuel Gas Co.	Black Band C & C Co., 10-5252	0	0.516	590 (52 hr.)	Oriskany gas well
15	Lincoln	Duval	0.27 mi. S. of 38°15′	3.21 mi. W. of 81°50′	2,353	Pen-Conemaugh	L. Mis-Pocono	Mary Lou Gas Co.	W. C. Holstein, 1-2	1	0	0	Berea oil well
16	Logan	Chapmanville	2.87 mi. S. of 38°00′	3.62 mi. W. of 81°55′	1,917	Pen-Kanawha	L. Mis-Pocono	South Penn N. G. Co.	Yawkey-Freeman, 77	0	0.220		Big Lime gas; abandoned
17	McDowell	Browns Creek	0.44 mi. S. of 37°30′	2.05 mi. W. of 81°35′	6,533	Pen-New River	L. Dev-Oriskany	Godfrey L. Cabot, Inc.	John Gilbert, Tr., 2-1069	0	0	0	Dry through Oriskany
18	Mason	Graham	1.17 mi. S. of 39°00′	3.99 mi. W. of 81°55′	1,668	Pen-Monongahela	L. Mis-Pocono	New Haven Gas Co.	Jennie Miller, 1	1½	0.090	350	Berea oil and gas well
19	Mingo	Hardee	1.04 mi. S. of 37°50′	0.68 mi. W. of 82°10′	4,138	Pen-Kanawha	M. Dev-Marcellus	United Carbon Co.	Cotiga Dev. Co., 1-1091	0	0.403	515 (14 hr.)	Brown Shale gas well
20	Pleasants	Union	3.91 mi. S. of 39°30′	2.35 mi. W. of 81°05′	5,577	Pen-Monongahela	L. Dev-Oriskany	J. C. Benedum	W. W. Campbell, 1	0	0.050		Oriskany gas show; abandoned
21	Putnam	Union	2.80 mi. S. of 38°40′	0.22 mi. W. of 81°45′	5,223	Perm-Dunkard	L. Dev-Oriskany	Godfrey L. Cabot, Inc.	J. L. McLean Hrs., 26-1088	0	0	0	Dry through Oriskany

TABLE 3.—(*Continued*)

Line No.	County	Magisterial District	Location		Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Property and Well No.	Initial Production per Day		Tubing or Casing Pressure, Lb. per Sq. In.	Remarks
			Latitude	Longitude						Oil Bbl.	Gas Millions Cu. Ft.		
22	Putnam	Pocatalico	0.04 mi. N. of 38°30′	4.20 mi. W. of 81°45′	1,691	Pen-Conemaugh	L. Mis-Greenbrier	Cumberland Gas Co.	Raymond City C. & T. Co., 1-CKP-2	0	0	0	Dry through Big Lime
23	Raleigh	Marsh Fork	0.28 mi. S. of 37°50′	3.02 mi. W. of 81°25′	6,703	Pen-New River	Sil-Niagara	Columbian Carbon Co.	Rowland Land Co., 1	0	0	0	Dry through Newburg
24	Raleigh	Marsh Fork	2.22 mi. S. of 37°50′	3.30 mi. W. of 81°25′	4,626	Pen-Kanawha	U. Dev-Portage	Columbian Carbon Co.	Rowland Land Co., 2	0	0	0	Dry through Portage
25	Raleigh	Clear Fork	3.52 mi. S. of 38°00′	0.98 mi. W. of 81°25′	2,700	Pen-Kanawha	L. Mis-Pocono	Columbian Carbon Co.	Rowland Land Co., 3	0	0	0	Dry through Berea
26	Raleigh	Marsh Fork	5.54 mi. S. of 38°00′	2.53 mi. W. of 81°30′	3,182	Pen-Kanawha	L. Mis-Pocono	Columbian Carbon Co.	Rowland Land Co., 4	0	0.103		Weir gas well
27	Upshur	Banks	1.82 mi. S. of 38°50′	2.02 mi. W. of 80°20′	2,187	Pen-Allegheny	U. Dev-Catskill	Hanley & Bird	W. F. Armstrong, 1-8	0	0.031	560 (60 hr.)	Gordon gas well
28	Upshur	Banks	2.33 mi. S. of 38°50′	2.43 mi. W. of 80°20′	4,316	Pen-Conemaugh	U. Dev-Chemung	Hanley & Bird	R. H. Fiddler, 1-1033	0	0	0	Dry through Benson
29	Wayne	Ceredo	4.28 mi. S. of 38°20′	2.12 mi. W. of 82°30′	4,168	Pen-Conemaugh	Sil-Clinton	Owens-Libbey-Owens	W. W. McComas, 1-654	0	0	0	Dry through Newburg
30	Wayne	Stonewall	0.32 mi. S. of 38°10′	2.00 mi. W. of 82°20′	3,085	Pen-Kanawha	M. Dev-Marcellus	Owens-Libbey-Owens	Hoard-Baldwin, 30-657	0	0.229	325 (50 hr.)	Big Injun and Brown Shale gas well
31	Wayne	Grant	1.33 mi. S. of 38°05′	3.18 mi. W. of 82°10′	3,847	Pen-Kanawha	M. Dev-Marcellus	Owens-Libbey-Owens	Louisa Collins, 1-662	0	0.222	517 (39 hr.)	Brown Shale gas well
32	Wayne	Lincoln	3.96 mi. S. of 38°00′	4.56 mi. W. of 82°20′	2,667	Pen-Kanawha	U. Dev-Portage	United Carbon Co.	Eliz. Coleman, 1-1135	0	1.108	300 (13 hr.)	Brown shale gas well
33	Wirt	Tucker	3.12 mi. S. of 39°05′	2.80 mi. W. of 81°30′	5,328	Perm-Dunkard	L. Dev-Oriskany	Columbian Carbon Co.	Virgie Mason, 1-	0	0.135		Oriskany gas show; abandoned
34	Wood	Slate	0.56 mi. S. of 39°10′	0.07 mi. W. of 81°30′	4,946	Perm-Dunkard	L. Dev-Oriskany	United Fuel Gas Co.	F. R. Hart, 1-5263	0	0	0	Dry through Oriskany
35	Wood	Slate	2.80 mi. S. of 39°10′	4.48 mi. W. of 81°25′	5,411	Perm-Dunkard	L. Dev-Oriskany	United Fuel Gas Co.	J. A. Goudy, 1-5264	0	0	0	Dry through Oriskany
36	Wyoming	Slab Fork	0.48 mi. S. of 37°40′	4.25 mi. W. of 81°25′	2,178	Pen-New River	U. Mis-Bluefield	Ravencliff Dev. Co.	Wyoming-Pocahontas C. & C. Co., 15-16	0	0.210	365 (48 hr.)	Princeton gas well
37	Wyoming	Huff Creek	3.30 mi. S. of 37°35′	0.26 mi. W. of 81°45′	6,002	Pen-New River	L. Dev-Oriskany	Godfrey L. Cabot, Inc.	John Gilbert, et al, Tr., 1-1068	0	0	0	Dry through Oriskany
38	Wyoming	Center	4.15 mi. S. of 37°40′	2.50 mi. W. of 81°30′	2,268	Pen-New River	U. Mis-Bluefield	Godfrey L. Cabot, Inc.	C. C. Sharp, 2-1070	0	0.127	520 (24 hr.)	Maxton(?) gas well
39	Wyoming	Center	3.94 mi. S. of 37°40′	3.25 mi. W. of 81°30′	3,061	Pen-New River	L. Mis-Pocono	Godfrey L. Cabot, Inc.	C. C. Sharp, 3-1071	0	0.260	740 (48 hr.)	Big Lime gas well
40	Wyoming	Oceana	2.57 mi. S. of 37°45′	4.26 mi. W. of 81°30′	3,100	Pen-New River	L. Mis-Pocono	Godfrey L. Cabot, Inc.	Watts Land Co., 2-1078	0	0	0	Dry through Weir
41	Wyoming	Baileysville	3.32 mi. S. of 37°35′	4.28 mi. W. of 81°35′	3,678	Pen-New River	L. Mis-Pocono	Godfrey L. Cabot, Inc.	John Gilbert, Tr., 3-1076	0	0.745	790 (18 hr.)	Berea gas well
42	Wyoming	Center	5.02 mi. S. of 37°40′	1.07 mi. W. of 81°35′	3,247	Pen-New River	L. Mis-Pocono	United Prod. Co.	W. M. Ritter Lbr. Co., 3-1118	0	2.475	796 (16 hr.)	Big Lime gas well

Wayne Counties, had commercial gas. None of these tests reached the so-called "Clinton" or White Medina sand of the Silurian.

DEVELOPMENT IN THE BIG LIME

For many years the Big Lime, or Greenbrier (L. Mis.), has produced substantial quantities of gas, and a little oil, in southwestern West Virginia. In later times, following the perfection of acidation technique, its possibilities have become increasingly important. In 1940 a small pool of oil, with wells ranging up to 400 bbl. per day after acidation, was opened in Kanawha County, within the Charleston gas field. At present, there are four new, flourishing, Big Lime gas pools in Kanawha, Putnam, Raleigh and Wyoming Counties. Initial open flow ranges from small quantities up to 13,000,000 cu. ft. per day. Many similar good wells are being found in other pools.

The Greenbrier, in northern West Virginia, is only 50 to 100 ft. thick, and is practically devoid of production, but it thickens southward to many hundreds of feet and contains various sandy or porous zones. With the certainty of good results from acidation, it seems apparent that vast quantities of new Big Lime gas will be recovered from the southern and southwestern counties.

TABLE 4.—*Oriskany Sand Wells, Jackson and Kanawha Counties and Adjacent Part of Putnam County, W. Va.*

County and Magisterial District	Completed before 1943				Completed in 1943				Total Number of Completed Wells	Number of Wells Drilling or Unreported, Jan. 1, 1944
	Gas Wells		Dry in Oriskany	Total Number of Wells	Gas Wells		Dry in Oriskany	Total Number of Wells		
	Number of Wells	Gas, M Cu. Ft.			Number of Wells	Gas, M Cu. Ft.				
Jackson County:										
Grant	3	829	0	3	0	0	0	0	3	1
Ravenswood	55	280,003	9	64	6	9,086	0	6	70	3
Ripley	187	1,089,588	6	193	46	137,171	5	51	244	8
Washington	55	413,752	9	64	9	39,664	1	10	74	3
Total	300	1,784,172	24	324	61	185,921	6	67	391	15
Kanawha County:										
Big Sandy	0	0	1	1	0	0	0	0	1	0
Cabin Creek	0	0	3	3	0	0	0	0	3	0
Charleston	1	88	0	1	0	0	0	0	1	0
Elk	92	376,211	13	105	0	0	0	0	105	0
Jefferson	0	0	1	1	0	0	0	0	1	0
Loudon	8	3,788	5	13	1	516	0	1	14	1
Malden	35	73,181	5	40	0	0	0	0	40	0
Poca	368	2,473,055	7	375	5	9,434	1	6	381	2
Union	21	41,007	3	24	4	8,323	2	6	30	1
Washington	1	254	3	4	0	0	0	0	4	0
Total	526	2,967,584	41	567	10	18,273	3	13	580	4
Putnam County:										
Union	9	8,176	1	10	9	21,593	1	10	20	1
Grand total	835	4,759,932	66	901	80	225,787	10	90	991	20

OPERATING TECHNOLOGY

Secondary recovery of oil, mostly by gas, or combined gas-air injection, is practiced in various old fields with good results. Acidation of the Big Lime, both for oil and gas, has become a routine method of developing or increasing production. Many old wells, presumably, will be revived to substantial new flow by this process. Some of the larger gas companies are now spending substantial sums on gas storage, principally in northern West Virginia, where the sands of exhausted pools afford suitable reservoirs fairly close to heavy consuming centers. Several new storage input wells were drilled, principally in Lewis County.

TABLE 5.—*Summary of New Development in West Virginia during 1943*

County	New Wells						Wells Drilled to Deeper Sands			
	Number of Wells	Oil Wells		Gas Wells		Dry Holes	Number of Wells	Production		Dry Holes
		Number of Wells	Bbl. per Day	Number of Wells	M Cu. Ft. per Day			Oil, Bbl. per Day	Gas, M Cu. Ft. per Day	
Barbour	1	0	0	1	111	0	0	0	0	0
Boone	43	6	44	34	8,250	3	2	0	312	0
Braxton	19	3	32	10	2,424	6	1	0	680	0
Cabell	2	0	0	2	226	0	0	0	0	0
Calhoun	37	12	121	20	7,801	5	4	0	432	0
Clay	64	9	63	47	27,786	8	2	0	252	0
Doddridge	5	1	32	4	701	0	2	0	50	1
Gilmer	45	6	69	28	8,485	11	3	0	365	1
Harrison	2	0	0	2	302	0	6	0	700	1
Jackson	70	0	0	61	187,204	8	0	0	0	0
Kanawha	79	3	72	59	77,043	17	4	0	844	1
Lewis	3	0	0	3	1,392	0	7	2	1,557	0
Lincoln	43	6	15	36	17,881	1	10	0	4,949	0
Logan	10	0	0	4	1,833	6	0	0	0	0
McDowell	1	0	0	0	0	1	0	0	0	0
Marion	4	0	0	1	322	3	2	0	58	1
Marshall	6	1	12	4	1,356	1	3	0	196	0
Mason	2	1	2	1	100	0	1	0	62	0
Mingo	5	1	1	4	1,900	0	0	0	0	0
Monongalia	9	0	0	6	1,461	3	2	1	12	0
Nicholas	1	0	0	1	189	0	0	0	0	0
Ohio	1	0	0	0	0	1	0	0	0	0
Pleasants	3	1	5	0	0	2	0	0	0	0
Putnam	55	0	0	48	50.547	6	0	0	0	0
Raleigh	13	0	0	6	4.854	7	0	0	0	0
Ritchie	31	6	147	15	8,350	10	3	0	195	1
Roane	7	2	29	2	496	3	0	0	0	0
Taylor	7	1	10	5	2,991	1	0	0	0	0
Tyler	4	1	5	0	0	3	0	0	0	0
Upshur	52	0	0	42	16,465	10	0	0	0	0
Wayne	16	0	0	14	7,258	2	0	0	0	0
Wetzel	11	4	14	3	517	4	4	0	660	2
Wirt	8	3	25	1	225	4	1	0	160	0
Wood	22	15	221	0	4,700	7	0	0	0	0
Wyoming	15	0	0	11	11,466	4	0	0	0	0
State total	696	82	919	475	454.735	137	57	3	11,484	8

PIPE LINES, COMPRESSOR STATIONS AND MARKETS

In northern West Virginia the 24-in. crude-oil line and the 20-in. products line of the Defense Plant Corporation were completed across Marshall County. In southern West Virginia, announcement has been made that Tennessee Gas and Transmission Co. will build 1156 miles of 24-in. gas line from Corpus Christi, Texas, to Kenova, W. Va., with a maximum capacity of 207,000,000 cu. ft., and an operating efficiency of about 175,000,000 cu. ft. per day. At Kenova the flow will divide, part of it going northward into Ohio through lines of Columbia Gas and Electric Corporation, and the larger part going eastward through 72 miles of new 18-in. line to Hope Natural Gas Co. at Cornwell Station, Kanawha County. Some additional trunk lines will be built to handle the further flow through Hope and Columbia lines to consuming centers in Pennsylvania and Ohio.

In Jackson and Clay Counties, substantial extensions of large gathering, or semitrunk, lines have been built to absorb new production in these areas.

In Braxton County, Pittsburgh and West Virginia Gas Co. completed a new compressor station 2 miles southeast of Rosedale, with four 300-hp. units. At Glenville, Gilmer County, the same company rebuilt its old steam compressor station by installing six-300-hp. gas-driven units. In Cabell County, West Virginia Gas Corporation built a 200-hp. compressor plant, to handle 2,500,000 cu. ft. of gas daily. In Jackson County, United Fuel Gas Co. added 1000 hp. to its Trace Fork compressor station; and in Kanawha County it built a 3000-hp. plant at Kenna.

Oil Prices

The price of oil remained pegged at $2.59 per barrel throughout the year. Figures are not yet available for the price of gas at the well mouth in 1943, but the U. S. Bureau of Mines figure of 12.2¢ per 1000 cu. ft. in 1942 is an advance of 0.1¢ over 1941. The reported price of 20.5¢ to be paid for Texas gas at the terminal of the new Texas-W. Virginia gas line may considerably increase the local field price in future years, because the gathering cost, from well mouth to main transmission lines, averages about 3¢ per 1000 cu. feet.

To a very considerable extent the failure of West Virginia to increase its production of oil and gas to quantities that are presently desirable may be attributed to shortage of materials and lack of adequate price incentives. On gas, in particular, no pipe line from Texas would have been necessary if an ample supply of pipe and a better gas price had been afforded to the operators. Plenty of gas, to meet demands for many years, remains in the ground.

County Summary

Table 5 shows by counties the new development in West Virginia during 1943. This information is compiled from all available sources, including trade journals, the West Virginia Department of Mines, the West Virginia Geological Survey, the special plat service offered by Veleair C. Smith, Management, and from private reports.

The various reports do not altogether agree, but Table 5 attempts to reflect a careful history of every well that was completed in West Virginia in 1943.

According to the Department of Mines, 878 permits to drill were issued, as compared with 870 permits in 1942.

Acknowledgments

The writer is glad to acknowledge helpful information through the year from the following organizations and individuals: West Virginia Department of Mines, Miss Marie Griffith; West Virginia Geological Survey, Mr. R. C. Tucker; Public Service Commission of West Virginia, Mr. M. F. Wright, Jr.; U. S. Bureau of Mines, Mr. F. S. Lott; Carnegie Natural Gas Co., Mr. Dan S. Keenan; Columbian Carbon Co., Mr. R. B. Anderson; Godfrey L. Cabot, Inc., Mr. H. J. Simmons, Jr.; Pittsburgh and West Virginia Gas Co., Mr. J. H. Newlon; Veleair C. Smith, Management, Mr. V. C. Smith; Tri-State Oil and Gas Co., Mr. H. P. McGinnis; United Carbon Co., Mr. I. G. Grettum; United Fuel Gas Co., Mr. J. L. Steward; West Virginia Gas Corp., Mr. J. E. Billingsley. Miss Mary C. Bollinger, secretary to the author, handled many of the statistics on production.

Oil Possibilities in Brazil

By S. Fróes Abreu*

The importation of liquid fuels in Brazil amounts to about 1,300,000 tons; 30 per cent of this total being gasoline for automobiles and airplanes. Statistics show an increasing consumption of gasoline notwithstanding the use, daily greater, of fuel alcohol, a domestic fuel of low cost in the producing areas.

The Brazilian market for petroleum products has shown a tendency to grow as the country has steadily developed—expansion of the industries in the areas already developed, and also the recent occupation and population of new zones.

The war has brought many difficulties to Brazil. It has limited the importation of petroleum products, which came mostly from the United States, Venezuela and Mexico. During the first days of the present crisis automobile and truck traffic was vastly curtailed; but the national activity in the production of more fuel alcohol, and principally in the development of producer gas, has done much to provide a solution for the transportation crisis threatened at the beginning of the gasoline shortage. Many thousands of cars and trucks in Brazil are now burning producer gas made from charcoal. Producer gas for automobiles has been improved by Brazilian engineers and many new types have appeared.

PRODUCTION

There is only one producing oil field in Brazil—the one in the State of Baía, near the Baía de Todos os Santos. The first producing oil well was drilled in Lobato in 1939 by the Federal Government following studies carried on in that area by Oscar Cordeiro, S. Froés Abreu, G. Paiva and J. Amaral. The field and laboratory work done by these men was published in 1936 in a paper entitled "Contribuicões para a Geologia do Petroleo no Reconcavo (Baía)," which indicated the potentialities of the area as an oil producer. After the discovery of the first producing well, the Brazilian Government issued a decree establishing an area, 60 km. in radius, as a National Reservation. This first well was drilled in Lobato.

In no other locality in Brazil is any petroleum produced. Although many wells have been drilled in the southern part of Brazil, on the northeastern coast and in the Amazon Basin, they yield nothing.

Actual production is below 1000 bbl. daily. The producing area covers Itaparica Island, Candeias and Aratú, Joanes Island and Lobato.

Since very little geological information was available, especially about subsurface structure, it was necessary to drill several wildcats in order to collect the data essential in the choosing of good locations. The United Geophysical Co. was contracted to perform a geophysical survey to clear up the major problems concerning the oil deposits in the Reconcavo beds.

The best wells in Reconcavo are on Itaparica Island, where the daily flow amounts to about 200 bbl.; in other sectors production is considerably lower and most of the wells are pumping. In the Aratú sector, near an area of very light oil, there is an important gas field, with wells producing about 10,000,000 cu. ft. daily.

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All the oil from Báía has a paraffin base and a low sulphur content, this paraffin generally causing considerable difficulty in pumping. Only the Aratú wells yield light oil, not viscous, which, by topping, gives a great quantity of gasoline. The analyses of Table 1 show the principal characteristics of Baía oils.

TABLE 1.—*Principal Characteristics of Baía Oil*

Characteristic	Lobato Oil (First Well)[a]	Aratú Oil[b]
Color	Dark brown	Brown
Sp. gr., A.P.I	41.5	43.2
Flashpoint	Below 86°F.	81°F.
Carbon residue, per cent	1.4	0.3
Water, per cent	0.4	
Water and sediment, per cent		3.4
Sulphur, per cent	0.02	Tr.
Paraffin, per cent	21	
Viscosity, abs. at 100°F., ctp		3.5
Distillation, atmospheric pressure:		
5 per cent	At 219°F.	At 257°F.
10 per cent	275°F.	293°F.
15 per cent	352°F.	325°F.
20 per cent	408°F.	352°F.
25 per cent	468°F.	385°F.
30 per cent	500°F.	410°F.
40 per cent	556°F.	466°F.
50 per cent	599°F.	525°F.

[a] Analysts: A Freire and F. Leal.
[b] Analyst: F. Pilar.

Besides the oils from the Baía field, there is now a limited production of mineral oils obtained from the distillation of oil shale and bituminous sandstone in the states of Paraná and São Paulo. In the Parahyba Valley, between the cities of Rio de Janeiro and São Paulo, a plant was erected to operate the big shale deposits of the Tertiary, which are found there. Production in this area has not yet been on a commercial scale, owing to certain technical difficulties. Some oil is produced, but only for experiments preceding the completion of this new plant.

In the state of Paraná, in São Matheus County, there is a small plant treating the black shale of the Iraty formation, which constitutes a very considerable but unexploited reserve of oil in potential stage. By destructive distillation this shale yields from 7 to 10 per cent crude oil of asphaltic nature, charged with unsaturated hydrocarbons and high in sulphur content. In many places the mining operations are made easy by the fact that the beds outcrop and form cliffs in the valleys. The oil produced in this small plant is redistilled in primitive stills, giving a gasoline that is utilized in the cars and buses of the county. Notwithstanding the high sulphur content and the unsaturated hydrocarbons, which have a very disagreeable odor and which produce gum compounds after some days of storage, the gasoline is much appreciated in this period of shortage, as it has a very high octane number.

The most important production of shale oil in Brazil is that of Guarey County, in southern São Paulo, from a homemade plant, which has been operating only about one year.

Because of the shortage of liquid fuels, as a consequence of the war, the Companhia Itatig is beginning to utilize the bituminous sandstones in the large areas it has leased in the state of São Paulo for producing oil. In this region there are large areas of Triassic sandstones cut by basic eruptives, showing extensive impregnation by bitumen. Despite great difficulties in obtaining steel plate and other materials needed for installing the plant, the Companhia Itatig has erected rotary kilns and is producing 40 bbl. of oil daily—a very fine example of war effort. The rock treated in this plant gives 6 to 7 per cent oil in volume, according to the degree of impregnation of the sandstone; in other words, about 16 to 20 gal. (of oil) is obtained per ton of sandstone treated, at a very reasonable cost, permitting commercial success.

The location of this works is very convenient, as it is very close to Sorocaba and the city of São Paulo, two important consumers of gasoline and fuel oil. The Companhia Itatig operates with two types of rotary kilns, one charged continuously and the other discontinuously. The oils produced are very different, as shown in Table 2.

TABLE 2.—*Guarei Oils* FROM DISTILLATION OF BITUMINOUS SANDSTONES

Characteristics	Discontinuous Retorts[a]	Continuous Retorts[a]
Atmospheric pressure, per cent:		
Up to 167°F	1.7	0.3
212°	3.2	3.6
257°	6.5	4.3
302°	11.5	8.3
347°	16.2	14.6
392°	20.2	19.9
437°	23.9	28.6
482°	28.9	37.3
527°	36.3	50.6
Vacuum, 40 m./m.:		
Up to 392°F	36.9	51.3
437°	37.1	51.6
482°	38.3	52.2
527°	41.8	53.6
572°	49.3	58.6
Color	Dark brown	Black
Sp. gr., A.P.I.	23.3	14.3
Flash point, deg. F	82	133
Carbon residue, per cent	1.1	5.9
Sulphur, per cent	1.5	1.3
Pour point	Below 53°F.	

[a] Analyst: E. Frias Rocha.

The Companhia Itatig was founded by Priolli Brothers, young Brazilians and pioneers in oil drilling in the state of Sergipe in northeastern Brazil. They did not find oil in Sergipe; only salt deposits, which are now being tested for alkali production (caustic soda). Now the company, under the presidency of Colonel Costa Neto, superintendent of a number of industries controlled by the Brazilian Government, is investigating the possibilities of manufacturing asphalt on a large scale, for paving purposes, to aid the program of building good roads for the nation.

The bituminous sandstones of the state of São Paulo, mainly in Guarei, Piramboia, and Porto Martins Counties, are very important. Such deposits occur also in the state of Santa Catarina, where they are very rich but far away from industrial centers and transportation facilities. Other asphalt and bituminous sandstones are known in the coastal belt of the state of Baía (Santo Amaro Island, Maraú and Ilhéos) but they have not yet been investigated.

REFINING

Petroleum refining is not yet an important industry in Brazil. Only two small refineries are treating very light crude oil imported from Equador and sometimes from the United States. They are the Refinaria Ipiranga S. A. in the state of Rio Grande do Sul and the Industrias Matarrazo de Energia in the city of São Paulo. Because of wartime transportation difficulties, these plants are working very irregularly. Many projects to build big refineries have been presented to the Government, but, for very complex and often political reasons, none has been agreed upon. Really one of the most important problems in national defense is the creation of a refining industry in Brazil, first operating with imported crude oil, until there is sufficient domestic production. As the country is very large, and there are densely populated centers in the northeast, the east and the south, it would be more suitable to build smaller refineries scattered among the most convenient localities, in order to ensure easy distribution throughout the consuming areas.

The Conselho Nacional de Petroleo, the official agency exploring the Baía fields and charged with the control of petroleum problems in Brazil, has installed some boilers, thus making a small plant for topping the light crude oil from Aratú. Gasoline produced here has a very low octane number (42) but is blended with ethyl alcohol of local production, which improves its quality and raises the octane rating of the fuel.

RESEARCH

For more than 40 years petroleum research has been carried on in Brazil, but irregularly because of a lack of proper financial support and detailed (basic) geological work. More than 20 wells have been drilled in the state of São Paulo, very few of which have yielded any oil and none gas. Some have been drilled by private concerns but for the most part they have been drilled by the Federal Geological Survey and the State of São Paulo Geological Survey. Their total does not come up to 150, however, even including the recent wells drilled on the National Reservation by the Drilling and Exploration Co., under the supervision of J. E. Brantly, of Los Angeles, California.

In the past four years some progress has been made in oil investigations in Brazil: the Serviço de Fomento da Produção Mineral, under the direction of Avelino Oliveira, drilled the first well in Lobato (1939); the Conselho Nacional de Petroleo contracted for drilling on the National Reservation and in the state of Alagoas, with the United Geophysical Co.; the Companhia Itatig drilled in Sergipe, discovering only large salt deposits; the Companhia Solipema drilled in Maraú without commercial success.

In 1938, the Federal Government published a map prepared by Avelino Oliveira, now Director of the Fomento da Produção Mineral and ex-geologist of the Conselho Nacional de Petroleo, showing potential petroleum areas in Brazil. He has considered five areas:

1. Area with greatest possibilities: Mezozoic and Cenozoic marine formations of the upper Amazon, Territory of Acre and the northeast coastal belt from Baía to Rio Grande do Norte. They cover about 492,650 sq. km., or about 5.7 per cent of the territory (country).

2. Areas of sedimentary rocks with possibility of oil; that is, the Paleozoic and Tertiary formations of Pará, Amazonas, the southern coast of Baía and Espirito Santo, and the Devonian and Gondwanic areas of southern Brazil covered by basaltic lava and Cretaceous sandstones. They cover about 2,335,850 sq. km., or 27.4 per cent of the country.

3. Areas of sedimentary rocks, for most part terrigenous with secondary or unknown oil potentialities. These are the Permian and carboniferous areas of Piauí, Maranhão, northern Goiaz, southeastern Pará and the "pantanal" (large bog) of Mato Grosso; they measure 934,250 sq. km., or 10.9 per cent of the country.

4. Areas not worthy of consideration for oil production: these have sedimentary terrigenous rocks in various states, occupying about 1,131,251 sq. km., or 13.3 per cent of the country.

5. Negative areas; that is, the crystalline shield and the metamorphic pre-Devonian rocks, occupying an area of 3,630,166 sq. km., or 42.7 per cent of the country.

Northeast Coastal Belt

The Northeast coastal belt was considered in 1938 by Avelino Oliveira as one of the most promising areas, and in 1939 the first producing well in Brazil was drilled there. The author of this paper has for many years been very confident of the possibilities of this area, despite divergent opinions held by many Brazilian geologists who were very skeptical before the discovery of the Lobato well in 1939 and the Itaparica wells in 1942. In a paper published by the author in 1936 with Glycon de Paiva and J. Amaral—"Contribuicões para a Geologia do Petroleo no Reconcavo (Baía)"—some theories about this area were explained, which subsequent drilling and geophysical work have confirmed. The opposing arguments, based on the supposition that the area was composed of very thin layers of Cretaceous without closed structures covering the crystalline shield, have been refuted in the Reconcavo, as wells have been drilled deeper than 7000 ft., always in the sediment of lower Cretaceous on upper Jurassic according to recent ideas. Salt water has been found and oil is being produced from about 20 wells.

The Baía oil comes from sands between 1600 and 3600 ft., interbedded in the shales of the Cretaceous or Jurassic age, which are covered in many places by terrigenous layers of the Tertiary "Barreiras Formation." This is a formation extending along the coast as far as the Guianas and capping older Tertiary formations (Eocenic and Miocenic) as well as Cretaceous limestone (Paraíba, Pernambuco). The sediments of the Reconcavo of Baía were named the "Serie Baía" by C. F. Hartt (Geology and Physical Geography of Brazil, Boston, 1870). It seems they extend south about 90 miles, where they become partly covered by Upper Cretaceous of Albian age with a developed limestone facies. Below this limestone in Maraú County, there are found conglomerates as in Lobato, showing oil impregnation on the sandstone cement. Rotary drilling in Maraú is made difficult by a loss of circulation due to the many big caves in the limestone, and any drilling program to be developed in this country must be preceded by geophysical work. In the state of Sergipe the Cretaceous basin is composed of marine deposits with many limestone outcrops. The thickness of the sediments is unknown but seems to be considerable; structural problems remain to be solved, and there is much work to be done before drilling can be started. The Companhia Itatig has drilled five wells and has found salt deposits about 300 ft. thick at 3600 ft. Thin layers of shale interbedded with the salt contained a greenish oil.

On the coast of Alagoas, the Conselho Nacional de Petroleo drilled some test wells where formerly a private company in Riacho Doce had obtained good indications and some gas.

Amazon Valley

Oil research is very difficult in the territory of Acre in the Amazon Basin, because the region is thickly forested, poor and very far from any civilized center, but in spite of the difficult conditions of the country, research must be undertaken, because its geological composition seems to be very favorable. Pedro de Moura, geologist of the C.N.P., surveyed part of this area, giving highly favorable reports. V. Oppenheim, formerly a geologist for the Brazilian Government, was of the same opinion. Geological work done in Acre shows the presence of Tertiary and Upper Cretaceous sediments, moderately folded and correlated with the Peruvian series of the Amazon Basin, studied by Singewald and now recognized as petroliferous, with wells producing considerable quantities (Pachitéa field). The discovery of oil in this part of Brazil would be very important in that it would create a new center of activity in the far west of the country.

In the lower Amazon the Paleozoic beds form a large syncline; north and south of the margin of the great river, parallel Silurian, Devonian and Carboniferous beds crop out, in many places covered by the Barreiras formation (Pliocenic terrigenous deposit). Attention was drawn to the oil possibilities of the area by E. P. Oliveira following the drilling program for coal development by Gonzaga de Campos to complete his field researches.

Drilling has been carried out in the lower Tapajos (Aveiros) in a search for oil in the Devonian beds. In Bom Jardim and Itaituba, the Geological Survey drilled six wells, finding some indications of oil and gas, but in the Monte Alegre wells none was found. According to E. P. Oliveira, the Silurian and Devonian formations in the Amazon Valley might be very interesting for oil research. In the Trombetas area the Silurian beds showed two characteristic zones: a zone of graptolites and a zone of mollusca. Both are of marine origin; in the first the sediment is very fine and contains diatoms and radiolares in great abundance; in the mollusca zone the rocks consist of hard clay sandstone and micaceous sandstone with marine layers of pure sandstone. In the graptolite sandstones are found simultaneously plant remains, diatoms, radiolares, sponges and foraminifera. In the Devonian beds, the Curuá formation, more than 300 ft. thick, is very rich in algae *Syprophyton Caudo-Galli*, constituting a polybitumen, and considered by E. P. Oliveira as a possible source bed for Devonian oil.

Southern Plateau

The southern plateau is very suitable for oil investigation. The geological conditions are good although rendered somewhat difficult by the interference of eruptive rocks; but climatic conditions are good, transportation is simple and mechanical facilities easily available from near-by industrial centers. With the exception of the Baía field, São Paulo is the area of the most extensive investigations, but oil in commercial quantities has not yet been found. Drilling tests have been made for more than forty years by private concerns, by the Federal and State Geological Surveys, but the results have not been very encouraging, since they have found indications of oil and gas in few of the wells.

The area in which research was carried on was the Permian Basin of the Gondwana series, which constitutes a large belt in the states of São Paulo, Paraná and Santa Catarina, extending southward and northward to Rio Grande do Sul and Goiaz. In the former three states indications of oil have been found in tar sands; albertite and viscous oil in the vesicules of basalts; and these have inspired some oil research.

The initial experiments in oil in the Gondwana were based on the possibility of getting oil derived from Iraty black shale and accumulated in the porous strata just above the source bed. Iraty shale is a layer of pyrobituminous shale interbedded with limestone and chert, many feet thick, containing such a quantity of organic matter that on destructive distillation it yields 20 to 25 gal. of oil per ton. All the early investigations in the state of São Paulo carried out by Gonzaga de Campos, Pacheco and E. P. Oliveira were based on a belief in Iraty as a source bed.

After traversing the Iraty beds, drilling was stopped on the glacial beds that underlie them. In no case has it reached the crystalline rocks, the deepest drilling having cut through part of the glacial deposit and stopped there.

In 1928 the Government of São Paulo contracted Chester Washburne to investigate oil possibilities, and after his long trip, this geologist presented a valuable report, the most complete study of oil geology in São Paulo. As a general idea, Washburne suggested searching for oil in the Devonian, which possibly occurs below the Permian in São Paulo. Notwithstanding this new orientation, Washburne admits the possibility of Permian oil derived from Iraty black shale and accumulated in adequate structures. According to his ideas, drilling might be deeper in order to search all the glacial beds and reach the Devonian, and well-defined structures might be found. Some of the structures drilled show no oil accumulation but baccolites of diabase, hence accurate geophysical investigations in the area would necessarily save money and time. Although it is safe to expect to find Devonian oil, the opinion of the author is that there is a possibility of finding Permian oil, which would be easier to reach and has not yet been investigated, although it exists in large areas in southern São Paulo, Paraná and Santa Catarina.

In the southeast of São Paulo, there are extensive outcrops of tar sands, whose origin is still a subject of controversy. Most Brazilian geologists believe the tar is derived from the natural distillation of Iraty shale by eruptives of Rhetic age, but the author is not convinced of this hypothesis. The sulphur content of the tar is low, whereas distillates of Iraty shale always yield oils high in sulphur; also, phenols are not present in the tar sands and are characteristic of the distillates of Iraty shale. Moraes Rego has shown that small quantities of oil obtained from some of the wells in São Paulo were quite different from Iraty distillates. In addition, the enormous quantities of tar sands outcropping in Guarey, Piramboia and Porto Martins would correspond to equivalent quantities of spent shale; in other words, quantities of distilled Iraty shale would be found, transformed into carbonaceous shales, seven or eight times the quantity of bitumen. Up to the present, carbonized Iraty shale has not been found in any well or outcrop of Iraty beds, as coke is found in the coal beds of Rio Grande do Sul, cut by diabase dikes. However, notwithstanding the many problems to be cleared up in Permian geology and the difficulties caused by eruptives in all the southern plateau, it is one of the most interesting areas for oil research. Since many wells were drilled in São Paulo without commercial success, and since geologists have not found good structures for oil accumulation in the best known area of the center of São Paulo—some showing no oil, but only *necks* and *laccolites* of eruptives—the attitude toward oil possibilities in southern Brazil has tended to be pessimistic.

A. I. Oliveira, with the knowledge that he had, put this region in secondary place in the geological map of 1938; Glycon de Paiva, also a recognized authority, in his paper, "Dificuldades específicas na Pesquisa de Petroleo no Sul do Brasil (1938)" (Specific Difficulties in Petroleum Research in Southern Brazil), puts in evidence the difficulties imposed by the presence of eruptives, but suggests certain tests, by electrical and seismic methods, to see what can be done in this field.

To Paiva it would seem very difficult to decide on locations from which to reach the Devonian beds, which outcrop in a very small area in São Paulo and Paraná, and which were exposed to erosion during a long geological period before Permian sedimentation. The conclusion of his paper is that there are in Brazil, regardless of the oil research problems, other areas "infinitely easier to work than the above mentioned" (southern plateau). "If private capital," continues Mr. Paiva, "wants to find Gondwana oil in Brazil, it must do it at its own expense and risk without the help of the Government. The Government aid would only be large leases very liberally granted, because of the tremendous difficulties encountered in the area." It is evident that the Government cannot give financial aid to private concerns, as it is already charged with the development of the National Reservation, the Baía field.

To private organizations all that is necessary are the guarantees granted by law, and possibly more efficacious help in the way of lightening duties on drilling machinery and research instruments, and greater facilities for foreign technical personnel.

Any drilling program in southern Brazil must be preceded by a systematic investigation of the tar sands and their relationship with basaltic eruptions. It would also be very useful to perform geochemical experiments in the tar-sand area and along the Iraty shale outcrops, where there is an odor of hydrocarbons. Mapping the interesting areas by means of photogrammetry, utilizing the modern process of trimetrogon, would be a very efficient help to oil investigations. Following this work, a geophysical survey done by seismographic and electrical methods, depending on the characteristics of the areas, and drill tests well placed will constitute the basis for locating producing wells in southern Brazil.

Chapter V. Refining

Review of Refinery Engineering for 1943

By Walter Miller,* Member A.I.M.E.

During the second year of America's active participation in the war the main objectives of the petroleum-refining industry were again to provide the four most important product needs for war: 100-octane aviation gasoline, toluene for T.N.T. production, high-quality lubricating oils for the needs of aviation and the armed forces, and petroleum chemicals for synthetic rubber manufacture. All other materials supplied by the petroleum industry took an inferior priority ranking, depending on the degree of essentiality.

To accomplish the above objectives the industry initiated and carried on a building program during 1942 and 1943 which will put those two years down in petroleum-refining history as the greatest construction years of all time, a record which will hold for decades to come. Led by an estimated total of $900,000,000 going into 100-octane and contributory plant investment, it is easy to picture a total of two billion dollars and more going into additional refining-industry plant investment during 1942 and 1943, most of it privately paid for, but a substantial part covered by R.F.C. Government money financing.

Some of the new plants will not be completed until 1944, but a large proportion of the program was finished and put into operation, adding substantially to the output of the four principal products during 1943.

Aviation Gasoline

The most important and spectacular activity of the refining industry is of course the 100-octane gasoline program necessitated by the fact that nearly 90 per cent of the requirements of the United Nations is being furnished by the United States.

Recent P.A.W. figures mention $900,000,000 as the cost of the construction looking to increasing the output of this all-important munition. Thirty-four major plants have been completed, 11 of them during the last quarter of the year. Thirty-eight more will be completed and put into operation during the first four or five months of 1944. Twenty-two additional plants authorized during 1943 are already well under way and scheduled for production late in 1944.

Early in 1942 the aim was to treble the capacity for making 100-octane gasoline then existing; later, plans were to make it five times as great, to match the increased warplane building program; and toward the end of the year the sights had been set at a still higher but unannounced target, representing six to seven times the early 1942 figure. Comparative figures issued at the end of 1943 enable one to guess a program by the middle of 1944 of eight to nine times the former production, with an ultimate production in 1944 of eleven or more times the early 1942 output.

It became obvious in 1943 that building of new units would be materially slowed because of delay in getting construction materials and that they would reach operation at considerably later dates than at first contemplated. This indicated a consequent shortage for some period of time of the fuel required by the armed services, unless other means could be found to bridge the gap.

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All efforts of the industry and P.A.W. were quickly applied in collaboration to solving this problem. Remarkable accomplishments were recorded in increasing the production from existing manufacturing facilities by adaptation and alteration of facilities taken out of other services; also in continually ferreting out and making available larger quantities of the various liquid petroleum products going into the final finished 100 octane. This "quick" development has been of incalculable value because the shortage of construction materials referred to did delay and is delaying completion of most of the 1942 authorized new major units by from three to six months beyond what had been hoped a year ago.

Among the things that contributed greatly to making up the deficiency caused by construction delay were the following: (1) The expedient of metamorphosing polymerization plants into codimer-producing units and finishing that product into commercial iso-octane of 92 to 98 octane number by utilizing the capacity of the industry's four large existing hydrogenation plants. (2) Removal of bottlenecks in existing units by changes increasing capacity at comparatively small expense of time and critical materials. (3) The making of cumene by chemically joining benzene and propylene. (4) Separation and utilization of iso-pentane from normal gasoline. (5) Increasing the output of alkylation plants by making more raw material available to installations developing higher than design capacity. (6) Searching the industry to bring out and make usable more of the straight-run, high-octane base gasoline contained in crude oils to combine with catalytically cracked gasolines for blending with the above high-octane components. Help was also received from the toluene program as the production of that product was found to exceed military requirements (in part brought about by the development of new explosives), toluene making a valuable 100-octane component. "Recently an Army General stated to Administrator Ickes: 'The job which has been done with 100 octane by the refinery experts of your staff and of the oil industry is one of the most amazing things I have ever witnessed. It is almost unbelievable. They have virtually squeezed it out of a hat.' "

Although a temporary shortage of 100 octane for training purposes has existed at different times and places in this country, never has there been any interruption in plane operations overseas because of its lack. A late-in-December statement by the chief of aviation fuel branch of the War Department is to the effect that refineries, working overtime as they are, are producing sufficient aviation gasoline to meet consumptive requirements for both training and overseas.

With the 38 new plants coming into operation from time to time during the next four months, production by May should surpass temporarily the constantly increasing demands of the augmented plane-production schedules and combat activities and should build up reserves to carry the situation safely over to the latter part of 1944. By that time the 22 additional units authorized in 1943 will be coming on the operating line, and the industry will be in a position to supply without fail all requirements that can be foreseen for the duration—constituting an enviable record of accomplishment!

Toluene for T.N.T.

The toluene problem of the industry is solved. Ordnance Department's estimates of ultimate requirements were somewhat reduced because of better experience and knowledge of possible rates of consumption and also by virtue of the development and manufacture of one or two new explosives, more suitable for certain objectives than T.N.T.

Hydroformer installations, the catalytic re-forming process which converts certain petroleum aliphatics to aromatics principally of the toluene and xylene types, and the attendant toluene extraction and purification plants were completed to a total capacity beyond the reduced estimated requirements. As a result of the lesser needs for explosives, from a quarter to a third of the toluene production as well as some of the xylene made is being diverted to the 100-octane activities, for which purpose these chemicals are almost as valuable a blending component as the commercial iso-octane being produced by the alkylation process installations. The high-octane and high-rich-mixture characteristics, and the favorable boiling ranges possessed by these chemicals, enable important increases in 100-octane output.

The Toluene Technical Committee, organized in 1942 under the auspices of Ordnance Department and working in collaboration with P.A.W., has continued to function with even greater effectiveness, with results apparent in the greater and quicker increases in production of this indispensable chemical. The activities and accomplishments of this committee will furnish one of the best illustrations of the war in accomplishments brought about by the wholehearted, full-scale co-operation of the industry with the armed forces and through P.A.W.

High-quality Lubricating Oils

Eight major and about twenty minor building projects for increasing output of war-purpose lubricating oils make up the total program since Pearl Harbor. Five of the major projects were announced by P.A.W. as being completed and in production by the end of 1943; the other three will be finished early in the new year. Most of the twenty minor projects have been finished with resultant greater output from the existing facilities with which these "bottleneck removers" are associated.

As the situation now stands, ample reserve stocks and current production capacity of lubricating oils exist for aviation and other military and lend-lease purposes. All necessary requirements for industrial and general uses are and will continue to be met, and reserves in stocks and production rates are sufficient to ensure all possible requirements. This activity, all financed by the industry without public funds, constitutes additional evidence, as stated by Deputy Administrator Davies of P.A.W., "of the patriotic co-operation which the petroleum industry has accorded the nation in its remarkable conversion from peacetime to wartime production."

This problem too is solved, and any apprehension previously felt has been removed.

Synthetic Rubber from Petroleum

During 1943 new estimates were made from time to time of requirements of the armed forces and lend-lease based on 1942 and 1943 actual experience. The quantity of 1,074,000 long tons of synthetic rubber per year recommended by the Baruch Committee in 1942 was changed to 850,000 long tons, the figures used in Progress Report No. 4 of Rubber Director Bradley Dewey, issued Nov. 10, 1943, and from which some of the following is gleaned.

On Oct. 31, 1943, construction with a rated capacity of 646,000 long tons was reported as completed. Full rated production of course is not immediately attainable upon completion of construction. The Report No. 4 estimates show an annual production rate for the last quarter of 1943 of 493,000 long tons and for the first quarter of 1944 at a rate of 665,000 long tons per year of all types of synthetics, the annual rate for the fourth quarter of 1944 being estimated at 896,000 long tons, indicating the completion then of the present program. In view, however, of the still existing shortages of construction materials and plant facilities, labor recruiting difficulties, and lessening of work effort, as well as other factors entering the picture, I believe that the above estimates are on the optimistic side by about three months and that Mr. Dewey's timing that "the next six to nine months will be the most difficult" will probably extend to twelve months. The ordinary civilian still faces a long period before removal of the restraints which now beset him.

The "butadiene from alcohol for rubber" part of the program is practically completed; and of the synthetic production rate at the end of the year, some 220,000 long tons per year is alcohol's contribution, with possibly another 10,000 to 25,000 per year in sight as operations are smoothed out, higher efficiency is attained, and minor bottlenecks are eliminated by virtue of increasing operating skill. Eleven units in three plants, identical in design and material requirements, were erected and put in operation within a minimum building time, speed having been made possible by special priorities. Sufficient alcohol has been allocated by W.P.B. to run the units at capacity.

Increasing natural rubber importations, even though on a small scale, are helpful, being estimated at 60,000 long tons for 1943 and 80,000 in 1944.

The petroleum refining program for producing raw materials, principally butadiene, from petroleum is behind earlier hopes and estimates. The same difficulties encountered in the 100-octane construction work, namely, shortage of man power in engineering and design and in field construction, and late availabilities of construction equipment and materials because of competition with the shipbuilding, aviation, munition, and armament programs, all made for delays in completion of plants. Three or four of the larger installations originally scheduled for considerably earlier completion dates are now expected to go into operation during the first four months of 1944, the largest of them all, the 120,000-ton per year installation at Port Neches, Texas, either late January or early February. The latest official report states that on Oct. 31, 1943, 39 per cent of the petroleum division units contributing raw materials to synthetic rubber were complete, either producing or going into production.

A number of changes were made in the production program in effect early in the year. Projected production of butyl rubber was cut to less than half, and greater emphasis placed on Buna S rubber from butadiene as more suitable for military usage. Neoprene rubber originally set up at 60,000 long tons a year is now planned for 40,000.

A good job has been done, although the present-day results are disappointing in view of earlier estimates and predictions; however, a comparison of the situation now, and as foreseen for a year from now, with the bleak outlook and the muddled, conflicting forces involved in the general problem a year and a half or two years ago, justifies a feeling of pride in what has been accomplished by all individuals and interests actively connected with synthetic rubber.

No specific information has been given out as yet of costs of synthetic rubber, and it is doubtful if any really reliable figures are currently available. Some time in 1944, however, it should be possible to evaluate the relative costs of synthetic rubber from alcohol and from petroleum products compared with crude plantation rubber from South America, Africa, and the East Indies.

Research and Development

Research and development efforts continued cooperatively under the joint auspices of the Petroleum Industry for War Council (P.I.W.C.) and Petroleum Administration for War (P.A.W.) largely through the activities of the Aviation Gasoline Advisory Committee (A.G.A.C.), the Toluene Technical Committee, and the Technical Committee, and the Technical Advisory Committee, with a large proportion of the more experienced refining technologists and experts in the industry actively engaged in the work.

Although previous reference has been made to the contributions of these technical efforts to the 100-octane and toluene program, the knowledge and ability and experience represented by this group is directed in many other directions, always of course with promotion of the war program as the guiding aim. Practically none of the important accomplishments are available for general publication, but all information as quickly as developed is made available to the directly interested technical workers and those refiners whose operations will be benefited thereby.

The immediate value to the war effort of this research work and the development of the new techniques and products is both indispensable and incalculable, but the value will not stop with the end of fighting. The entire refining industry is being lifted to a higher plane of accomplishment, to a level which will quickly broaden its peacetime accomplishments to a degree which would have taken years of ordinary progress. The impact of the industry on chemistry and chemicals of the future, the experience leading to better products and better utilization of the less valuable fractions of petroleum by conversion to materials for new fields, will unquestionably increase petroleum's contribution to the well-being of mankind to degrees beyond anything hitherto accomplished.

Catalytic Processes

Progress made in catalytic operations of all kinds is already discernable. Catalytic cracking is rapidly displacing the comparatively inefficient thermal cracking operations and this trend will be extended much further after the war as construction materials become available and as designs for smaller-scale catalytic cracking units are developed for the intermediate and smaller-size refining units. Catalytic cracking establishes a trend to the conservation of crude oil in that more and better motor fuel and furnace oil is made possible with a material reduction in production of heavy low-value industrial fuel oil, largely a by-product of thermal cracking. Catalytic processes will be utilized to a continuing greater extent in making liquid fuels out of normally gaseous products and converting to bases for the manufacture of chemicals. Catalytic processes will bridge the gap to the next conservation step of catalytic oil hydrogenation, technically and practically worked out but not now commercially feasible. Catalytic operations coupled with oil hydrogenation will put off appreciably the day when other and more costly sources of hydrocarbon liquids will have to be tapped to eke out dwindling supplies of crude.

Crude Oil and General Products

Crude-oil charges to stills increased from approximately 3,600,000 barrels per day in January 1943, to around 4,200,000 barrels in December, for an average of 3,910,000 for the year. The outlook for 1944 is for still higher runs to the extent the crude oil can be made available up to say another 200,000 to 300,000 barrels daily, as the war absorbs continually more petroleum products of all kinds.

Motor gasoline rationing started in the Eastern area in 1942 because of shortage of transportation facilities brought about by the submarine sinkings of tankers. Transportation conditions improved greatly, although not completely, during 1943 as the "Big Inch" pipe line and other pipe lines and extensions and reversals came gradually into operation and a few more tankers became available; but concurrently increasing war requirements cut into quantities available for other uses. With military uses taking 600,000 barrels of gasoline daily and more to come out of the approximately 1,800,000 barrels available, it was necessary to extend general gasoline rationing countrywide and reduce the civilian consumption still further. The farmer as a food producer couldn't be cut down, and the trucker engaged in transporting military necessities couldn't be cut down—the saving had to come from reduction of the more or less nonessential civilian driving.

At the beginning of the year the situation regarding industrial fuel oil was critical; and refineries were cutting down gasoline yields to increase the output of that commodity. It was feared factories and railroads would be hampered. But aided by higher allowable prices for the extra fuel produced, that job was so well done that after a few months it was possible to change the trend back more nearly to normal; and sufficient industrial fuel is on hand and currently being made to take care of all requirements.

A shortage of kerosene in the Eastern part of the country threatened at the year end. Marshaled by P.A.W., refiners were stepping into the breach, increasing yields at the expense of other commodities, so this temporarily critical situation should be taken care of fairly satisfactorily.

Gasoline produced for the year was slightly higher than in 1942, about 1 per cent, in spite of a 2.7 per cent drop in yield, the increase being brought about by the higher crude runs of about 250,000 barrels a day and utilization of greater quantities of casinghead gasoline by refiners.

Practically all products are likely to continue tight in the coming year, especially on the Eastern seaboard. Stocks are generally low, and little reserves are left. When emphasis is placed on one product, and more of that is produced, it means lesser production of some other product or products, as light domestic furnace oil when making more kerosene. Expedience will continue to govern as temporary emergencies arise; and through P.A.W., refiners will cooperate to handle such special situations.

POSSIBLE OTHER FUTURE SOURCES OF PETROLEUM LIQUIDS

Although a total ultimate discovery and production of 35 billion barrels of crude oil has been estimated and guessed at, compared with the estimated 20 billion barrels comprising the present proved reserve, higher figures up to 100 billion have been mentioned. Some fear the new discoveries may not come fast enough to meet the increasing requirements of the country; accordingly other possible sources of hydrocarbon material have been discussed and speculated upon:

1. Oil shale is one such source, known deposits in this country containing an estimated 400 billion tons with an estimated recoverable content of 90 to 100 billion barrels of oil, available as and when economic conditions justify the necessarily large installations and investments.

2. Wider interest has been stimulated in the "tar" sands, oil-saturated sands in the Athabaska region in northern Alberta in which small-scale operations have been carried on for some time. Their location is about 500 miles north of the United States border and 500 miles east of the Pacific coast line. An enormous deposit is evidenced, estimates ranging from 100 billion to 250 billion barrels of potential oil.

3. Hydrogenation of coal to liquids, an expensive but demonstrated operation carried out in England and Germany with a practically unlimited supply of raw materials, is another potential source. A bill before Congress at the end of the year, already approved by the Senate, would

appropriate $30,000,000 for building some fair-size demonstration plants by the Government to work out design, operating, and economic phases on the theory that it was a problem for Government and not private business to carry on for the general future good of the country as a whole.

4. A fourth source is the making of synthetic motor gasoline from the great natural-gas reserves in this country, a reserve which has been estimated as 95 trillion cubic feet and from which possibly ten billion barrels of liquid petroleum products could be obtained by using a modified catalytic liquefying process based on the Fisher-Tropsch methods used in Germany for making synthetic gasoline and other petroleum equivalents from coal.

The question as to when and how the above sources will have to be utilized and in what order they will be tapped and what economic price levels for crude oils will have to be established and maintained to justify the new sources with their materially higher per-barrel over-all cost will be answered in the future. Apparently there is assurance of an ample supply of gasoline and other petroleum liquids for succeeding generations at a price.

Production

Oil Developments in the Texas Panhandle during 1943

By Gail F. Moulton,* Member A.I.M.E.

In spite of an increase of 7 cents per barrel in the posted price of oil for the Panhandle field effective June 16, 1943, there was less drilling during 1943 than in any of the several previous years. The drilling statistics are compiled as Table 2 and show the material increase in the percentage of the total number of field wells completed as dry holes. This increase suggests that the productive area of the field is largely drilled up on the well-spacing pattern now followed and that new discoveries will be required to permit any important new activity in the area. The fact that only four wildcats were drilled in the area during the year indicates that some new prospecting technique or some new point of view is required to stimulate exploration. No new producing areas were discovered during 1943 and no additions to oil reserves were made through extensions or discovery of new pays. Accordingly, the proven reserves in the area declined by the amount of the production, or nearly 31 million barrels. These results of drilling are similar to those obtained during 1942, when no new oil areas were discovered as a result of wildcatting, a total of five wildcat wells in 1942 resulting in four failures and one gas-field discovery of undetermined merit.

Table 1.[a]—*Oil Production in Texas Panhandle*

Field	Total Oil Production, Bbl.		Wells, December 1943		
	To End 1943	During 1943	Flowing	Pumping	Total
Carson County	47,153,206	4,112,016	8	705	713
Gray County	211,955,378	13,600,612	15	2,389	2,404
Hutchinson County	178,125,706	11,391,525	10	2,025	2,035
Moore County	5,463,660	162,688	3	10	13
Wheeler County	23,443,133	1,491,451	2	409	411
	466,141,083	30,758,292	38	5,538	5,576
Potter County	33,822	Abandoned			

[a] Data from published reports Oil and Gas Division, The Texas Railroad Commission.

The statistics of oil production are shown on Table 1. Production during 1943 was almost exactly the same as for 1942, according to reports by the Oil and Gas Division of the Texas Railroad Commission. The number of oil-producing wells reported by the Commission increased during the year by 163 to a total of 5576 as of December.

Table 2.[a]—*Summary of Drilling Operations, Texas Panhandle*

Field Wells	1942		1943	
	Number	Per Cent	Number	Per Cent
Oil wells	277	77.5	136	71.5
Gas wells	63	17.7	30	15.9
Dry holes	17	4.8	24	12.6
Total field wells	357	100.0	191	100.0
Wildcat wells	3		4	
Total completions	360		195	

[a] Data from *The Oil Weekly*.

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